CHAPTER 2

COMPONENT TESTING

LEARNING OBJECTIVES

Upon completion of this chapter, you will be able to do the following:

1. Explain the importance of testing individual electronic components.
2. Identify the various methods of testing electron tubes.
3. Identify the various methods of testing semiconductors.
4. Identify the various methods of testing integrated circuits.
5. Identify the various types of testing batteries and their characteristics.
6. Identify the various methods of testing rf attenuators and resistive loads.
7. Identify the various methods of testing fiber-optic devices.

INTRODUCTION TO COMPONENT TESTING

It is imperative that you be able to troubleshoot an equipment failure to the component level. In the majority of cases, Navy technicians are expected to troubleshoot and identify faulty components. This chapter, "Component Testing," will acquaint you with alternative methods of testing various components and their parameters. A quick glance at the Navy's mission and concept of operation explains why we, in most cases, must be able to troubleshoot to the faulty component level. A ship must be a self-sustaining unit when deployed. Storage space is a primary consideration on most ships and a limiting factor for storage of bulky items or electronic modules as ready spares. Therefore, it is practical to store only individual components common to a great number of equipment types. This of course, limits the larger replacement modules available to you during troubleshooting.

Q-1. Why are most ships limited in their ability to stock replacement modules for repair of electronic equipment?

TESTING ELECTRON TUBES

In equipment that uses vacuum tubes, faulty tubes are responsible for more than 50% of all electronic equipment failures. As a result, testing of electronic tubes is important to you. You can determine the condition of a tube by substituting an identical tube known to be good for the questionable one. However, indiscriminate substitution of tubes is to be avoided for at least the following two reasons: (1) detuning of circuits may result and (2) a tube may not operate properly in a high-frequency circuit even though it performs well in a low-frequency circuit. Therefore, your knowledge of tube-testing devices and their limitations, as well as correct interpretation of the test results obtained, is indispensable for accurate and rapid maintenance.

Because the operating capabilities and design features of a tube are demonstrated by its electrical characteristics, a tube is tested by measuring those characteristics and comparing them with representative values established for that type of tube. Tubes that read abnormally high or low with respect to the standard are suspect. Practical considerations, which take into account the limitations of the tube test in predicting actual tube performance in a particular circuit, make it unnecessary to use complex and costly test equipment with laboratory accuracy. For most applications, testing of a single tube characteristic is good enough to determine tube performance. Some of the more important factors affecting the life expectancy of an electron tube are listed below:

- The circuit function of the tube
- Deterioration of the cathode coating
- A decrease in emission of impregnated emitters in aging filament-type tubes
- Defective seals that permit air to leak into the envelope and oxidize the emitting surface
- Internal short circuits and open circuits caused by vibration or excessive voltage

If the average receiving tube is not overdriven or operated continuously at maximum rating, it can have a life of at least 2,000 hours before the filament opens. Because of the expansion and contraction of tube elements during the process of heating and cooling, electrodes may lean or sag, which causes excessive noise or microphonics to develop. Other electron-tube defects are cathode-to-heater leakage and nonuniform electron emission of the cathode. These common tube defects contribute to about 50% of all electronic equipment failures. For this reason you should immediately eliminate any tube known to be faulty. However, avoid blind or random replacement of good tubes with fresh spares. The most common cause of tube failure is open filaments. Evidence of a tube defect is often obvious when the filament is open in glass-envelope tubes. You will also notice the brighter-than-normal cherry-red glow of the plate when the plate current is excessive. Also, when the tube becomes gassy or when arcing occurs between electrodes, you will probably have visual indication. Metal-encased tubes can be felt for warmth to determine if the heater is operating. You can tap a tube while it is operating in a circuit to reveal an aural indication of loose elements within the tube or microphonics, which are produced by loose elements.

Most tubes are extremely fragile and subject to damage during shipment. When you replace a tube, never make the assumption that the new tube is good because it’s new. You should always test tubes before installing them.

Q-2. What is the most common cause of electron tube failure?

SUBSTITUTION METHODS

Substituting with a tube known to be in good condition is a simple method of testing a questionable tube. However, in high-frequency circuits tube substitution should be carried out in a logical sequence. Replace tubes one at a time so that you can observe the effect of differences in interelectrode capacitance in the substituted tubes on tuned circuits. The tube substitution test method cannot be used to advantage in locating more than one faulty tube in a single circuit for two reasons: (1) If both an rf amplifier tube and IF amplifier tube are defective in a receiver, replacing either one will not correct the trouble; and (2) if all the tubes are replaced, there is no way for you to know what tubes were defective. Under these conditions, using test equipment designed for testing the quality of a tube saves you valuable time.

Q-3. What is the most accurate method of determining the condition of an electron tube?

NOTE ON SYMBOLS USED IN THE FOLLOWING SECTIONS: IEEE and ANSI standards (see inside front cover) are used to define various terms, such as anode (plate) current, anode voltage, and anode resistance. This book uses E_a for anode voltage, I_a for anode current, and r_a for anode resistance. These are the same as E, I_p, and $_{rp}$ that you will see elsewhere. This module uses the terms anode and plate interchangeably.

ELECTRON TUBE TESTERS

A representative field type of electron tube tester designed to test all common low-power tubes is shown in figure 2-1. The tube test conditions are as close as possible to actual tube operating conditions and are programmed on a prepunched card. The card switch (S101, fig. 2-1) automatically programs the tube test conditions when it is actuated by a card. A card compartment on the front panel of the tester provides storage for the most frequently used cards. The cover of the tester (not shown) contains the operating instructions, the brackets for storing the technical manual, the power cord, the calibration cell for checking the meter and short tests, the calibration cards, the blank cards, and a steel hand punch.

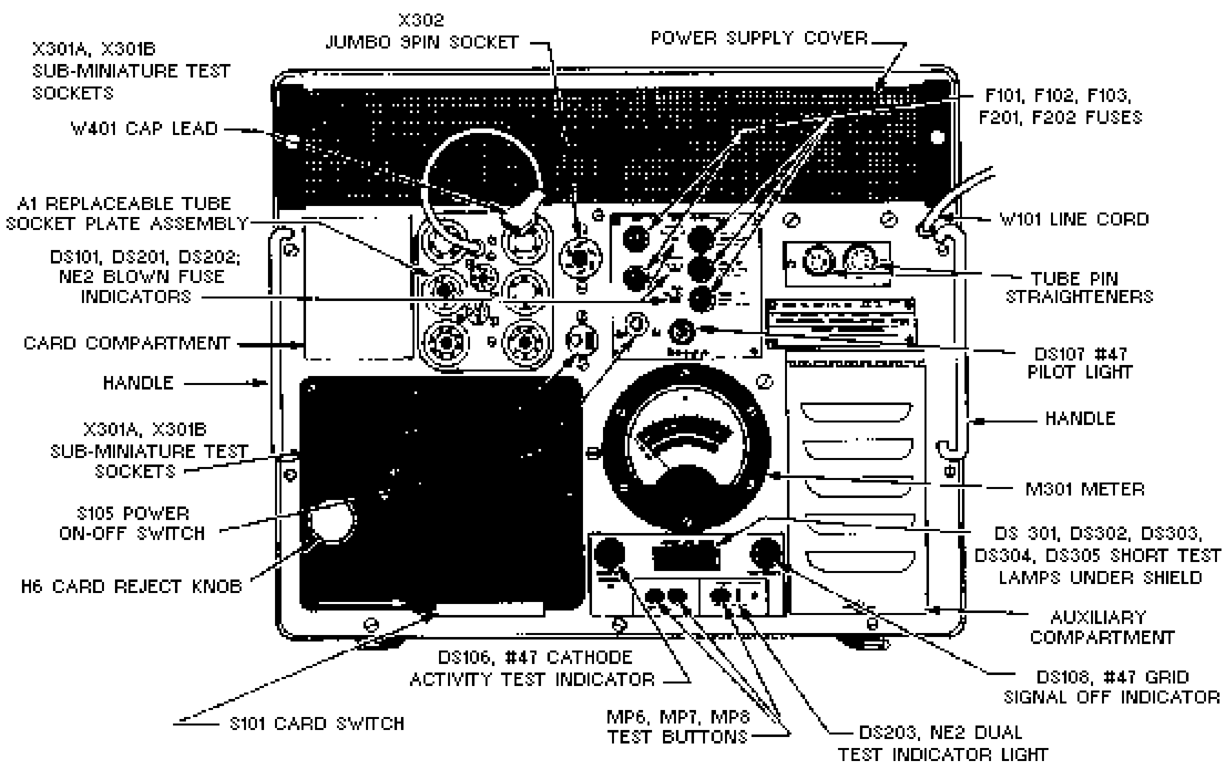

Figure 2-1.—Electron tube tester.

Front Panel

When a prepunched card is fully inserted into the card switch (S101), a microswitch is actuated that energizes a solenoid, causing the card switch contacts to complete the circuit. The card switch has 187 single-pole, single-throw switches arranged in 17 rows with 11 switches in each row. The card is used to push the switches closed; thus, the absence of a hole in the card is required to actuate a switch.

The meter (M301) contains four scales. The upper scale is graduated from 0 to 100 for direct numerical readings. The three lower scales, numbered 1, 2, and 3, are read for LEAKAGE, QUALITY, and GAS, respectively. Each numbered scale includes green and red areas marked GOOD and REPLACE. Inside a shield directly in front of the meter are five neon lamps (DS301 through DS305), which indicate shorts between tube elements.

The number 2 pushbutton (MP6) is used for transconductance, emission, and other quality tests (described later). The number 3 pushbutton (MP7) is used to test for the presence of gas in the tube envelope. The number 4 pushbutton (MP8) is used for tests on dual tubes. A neon lamp (DS203) lights when pushbutton number 4 is to be used. Eleven tube test sockets are located on the panel, plus tube pin straighteners for the 7- and 9-pin miniature tubes.

The power ON-OFF spring-return toggle switch (S105) turns the tester on by energizing a line relay. The pilot light (DS107) lights when this relay closes. Above the power ON-OFF switch are five fuses. Fuses F101, F201, and F202 protect circuits in the tester not protected by other means and have neon lamps to indicate when they have blown. Fuses F102 and F103 protect both sides of the power line.

Auxiliary Compartment

A group of auxiliary controls covered by a hinged panel is used for special tests and for calibration of the tester. Two of these controls, labeled SIGNAL CAL (R152 and R155, fig. 2-2), are used with special test cards for adjusting the regulation and amplitude of the signal voltage. A pushbutton labeled CATH ACT (S302D) is used for making cathode activity tests. When this button is pressed, DS106 on the front panel (fig. 2-1) lights, and the filament voltage of the tube under test is reduced by 10%. Results of the test are read as a change in reading on the numerical meter scale.

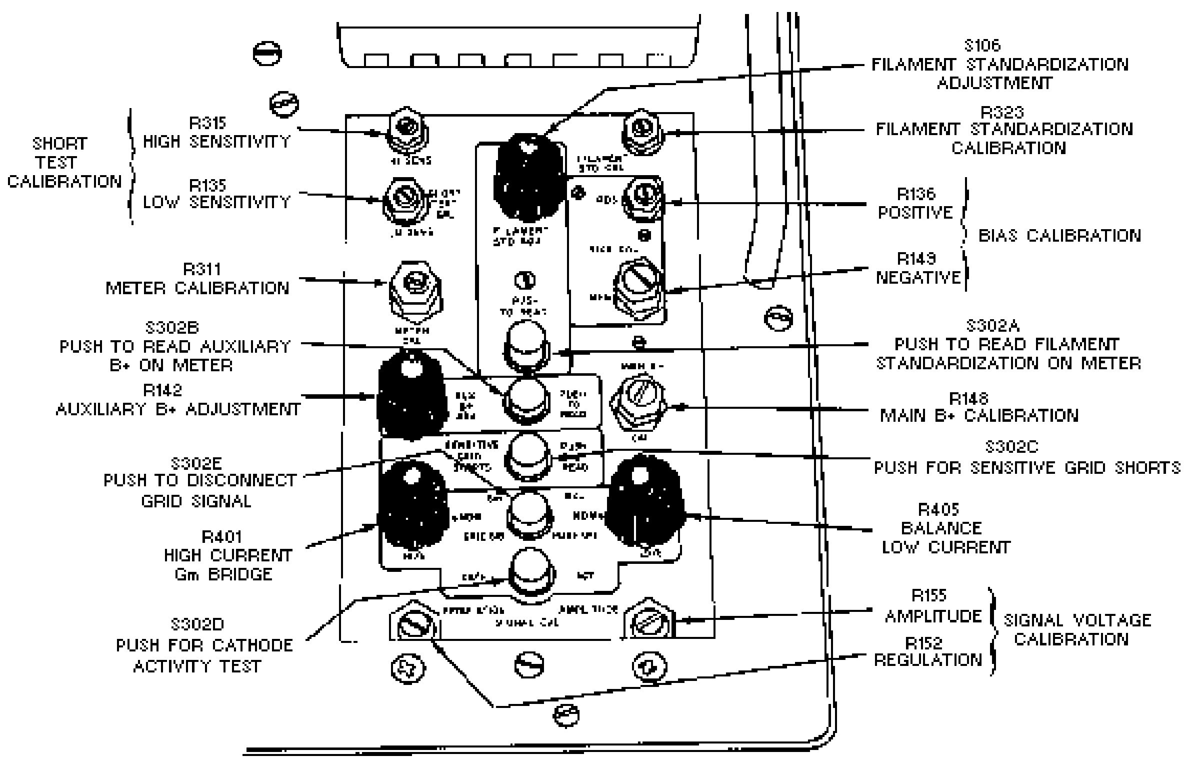

Figure 2-2.—Auxiliary compartment.

Pushbutton S302E and potentiometers R401 and R405 (fig. 2-2) are used for balancing the transconductance (Gm) bridge circuit under actual tube operating current. Pressing S302E removes the grid signal and allows a zero balance to be made with one potentiometer or the other, depending upon whether the tube under test is passing high or low plate current. Lamp DS108 on the front panel lights when S302E is pressed. Pushbutton S302C is used for checking grid-to-cathode shorts at a sensitivity much higher than the normal tests. Results of this test are indicated by the short test lamps on the front panel.

Certain special tests require the use of a continuously adjustable auxiliary power supply. By pressing pushbutton S302B, you may use meter M301 to read the voltage of the auxiliary power supply on meter M301. This voltage may be adjusted by the use of the potentiometer R142. The rest of the potentiometer controls are calibration controls and are adjusted by the use of special calibration cards and a calibration test cell.

All circuits in the tester, except the filament supply, are electronically regulated to compensate for line voltage fluctuations. The filament supply voltage is adjusted by pressing pushbutton S302A and rotating the filament standardization adjustment switch S106 until meter M301 reads midscale.

Program Cards

The circuits to be used in testing are selected by a prepunched card. These cards are made of tough vinyl plastic material. The tube numbers are printed in color on the tabs of the cards and also at the edge of the card for convenience in filing. A special card is provided to use as a marker when a card is removed for use. Blank cards are provided so that additional test cards may be punched for new tubes that are developed or to replace cards that have become unserviceable.

Operation

Before operating the tester for the first time, and periodically thereafter, you should calibrate it using the calibration test cards as described in the equipment technical manual.

NORMAL TESTS.—The tester is equipped with a three-conductor power cord, one wire of which is chassis ground. It should be plugged into a grounded 105- to 125-volt, 50- to 400-hertz outlet.

Before operating the tester, open the auxiliary compartment (fig. 2-2) and ensure that the FILAMENT STD ADJ and the Gm BAL knobs are in the NOM position. The GRID SIG and CATH ACT buttons (S302E and S302D) should be up and lamps DS108 and DS106 on the front panel should be out.

Turn on the tester and allow it to warm up for 5 to 10 minutes, then press the CARD REJECT KNOB (fig. 2-1) down until it locks. If a nontest card is installed in the card switch, remove it. This card is used to keep the switch pins in place during shipment and should be inserted before transporting the tester.

Plug the tube to be tested into its proper socket. (Use the pin straighteners before plugging in 7- and 9-pin miniature tubes.) Select the proper card or cards for the tube to be tested. Insert the card selected into the slot in the card switch until the CARD REJECT KNOB pops up. The card will operate the tester only if it is fully inserted and the printing is up and toward the operator. Do not put paper or objects other than program cards into the card switch, because they will jam the switch contacts. If the overload shuts off the tester when the card is inserted in the switch, check to see that the proper card is being used for the tube under test and that the tube under test has a direct interelement short.

As soon as the card switch is actuated, the tube under test is automatically subjected to an interelement short test and a heater-to-cathode leakage test. A blinking or steady glow of any of the short test lamps is an indication of an interelement short. If the short test lamps remain dark, no interelement shorts exist within the tube. If a short exists between two or more elements, the short test lamp or lamps connected between these elements remain dark, and the remaining lamps light. The abbreviations for the tube elements are located on the front panel just below the short test shield so that the neon lamps are between them. This enables the operator to tell which elements are shorted. Heater-to-cathode shorts are indicated as leakage currents on the #1 meter scale. If the meter reads above the green area, the tube should be replaced. A direct heater-to-cathode short causes the meter to read full scale.

To make the QUALITY test, push the number 2 button (fig. 2-1) and read the number 2 scale on meter M301 to determine if the tube is good. (This test may be one of various types, such as transconductance, emission, plate current, or voltage drop, depending upon the type of tube under test.)

To test the tube for GAS, press the number 3 button and read the number 3 meter scale. The number 2 button also goes down when number 3 is pressed. If a dual tube having two identical sections is being tested, the neon lamp (DS203) will light, indicating that both sections of the tube may be tested with one card. To do this, check the tube for shorts, leakage, quality, and gas as described previously; then hold down button number 4 and repeat these tests to test the second section of the tube. Dual tubes with sections that are not identical require two cards for testing. A second card is also provided to make special tests on certain tubes.

AUXILIARY TEST.—As mentioned previously, two special tests (cathode activity and sensitive grid shorts) may be made by use of controls located in the auxiliary compartment (fig. 2-2). The cathode activity test (CATH ACT) is used to indicate the amount of useful life remaining in the tube. By reducing the filament voltage by 10 percent and allowing the cathode to cool off slightly, the ability of the cathode as an emitter of electrons can be estimated. This test is made in conjunction with the normal quality test.

To make the CATH ACT test, allow the tube under test to warm up, press button number 2 (fig. 2-1), and note the reading of scale number 2 on meter M301. Note also the numerical scale reading on M301. Next, lock down the CATH ACT button (fig. 2-2), wait for about 1.5 minutes, then press button number 2 (fig. 2-1) again and note the numerical and number 2 scale readings on meter M301. The tube should be replaced if the numerical reading on M301 differs from the first reading by more than 10 percent or if the reading is in the red area on the number 2 scale.

It is sometimes desirable to check certain tubes for shorts at a sensitivity greater than normal. To make the SENSITIVE GRID SHORTS test, push S302C (fig. 2-2) and note if any short test lamps (fig. 2-1) light.

HIGH-POWER HF AMPLIFIER TUBE TESTS

You normally test high-power amplifier tubes, which operate in the low-to-high frequency range, in the transmitter in which they are to be used. When you operate the tube in a transmitter, its condition can be determined by using built-in meters to measure the grid current, plate current, and power output and comparing those values with those obtained when using tubes known to be good.

Q-4. Normally, how are high-power rf tubes tested?

Klystron Tube Tests

You can check low-power klystron tubes for gas, frequency of the output signal, and output power by placing them in the equipment where they are to be used. You measure the beam current, output frequency, and output power with the transmitter's built-in test equipment. You can check the output of klystrons used as receiver local oscillators by measuring the current in the crystal mixer unit.

Klystron tubes that remain inoperative for more than 6 months may become gassy. This condition occurs in klystrons installed in stored or spare equipment as well as in klystrons stored as stock supplies. Operation of a gassy klystron at its rated voltages will ionize the gas molecules and may cause excessive beam current to flow. This excessive beam current may shorten the life of the klystron or produce immediate failure. You can detect gas in a klystron tube by setting the applied reflector voltage to zero and slowly increasing the beam voltage while observing a meter that indicates the beam current - excessive beam current for a specific value of voltage indicates that the tube is gassy.

A gassy klystron tube can usually be restored to serviceable condition if you temporarily operate it at reduced beam voltage. Eight hours or more of reduced voltage operation may be required for klystrons that have been inoperative for periods in excess of 6 months.

The beam current is also an indication of the power output of the klystron. As klystrons age they normally draw less beam current; when this current decreases to a minimum value for a specific beam voltage, the tube must be replaced. You can usually determine the power output of transmitter klystrons by measuring the transmitter power output during equipment performance checks.

Q-5. What should you do if a klystron becomes gassy?

Traveling-Wave Tube

You can usually test a traveling-wave tube (twt) in the equipment in which it is used. When the twt is installed, you can usually measure the collector current and voltage and check the power output for various inputs. Any deviation greater than 10% from normal specifications may be considered to be an indication of a defective tube. Most amplifiers are supplied with built-in panel meters and selector switches so that the cathode, anode, helix, focus, and collector currents may be measured. Thus, continuous monitoring of amplifier operation and tube evaluation is possible. Adjustments usually are provided for you to set the helix, grid bias, and collector voltages for optimum operation. If variation of these controls will not produce normal currents and if all voltages are normal, you should consider the tube to be defective and replace it with a new tube or one known to be in good operating condition. To avoid needless replacement of tubes, however, you should make an additional check by measuring the input power and output power and determining the tube gain. If, with normal operating conditions, the gain level drops below the minimum indicated value in the equipment technical manual, the tube is defective.

Q-6. When used as an amplifier, what is the best indication that a twt is operating properly?

In the absence of special field-test sets, you may construct a laboratory test mock-up similar to that shown in figure 2-3. Because of the variations in power and gain between tubes and the large frequency ranges offered, we can illustrate only a general type of equipment. The equipment you select must have the proper range, impedance, and attenuation to make the test for a specific type of twt. To make gain measurements, you turn the switch shown in figure 2-3 to position 1 and set the precision attenuator to provide a convenient level of detector output. Then turn the switch to position 2 and insert attenuation until the detector output level is identical to that obtained without the twt in the circuit. The gain of the traveling-wave tube is equal to the amount of added attenuation.

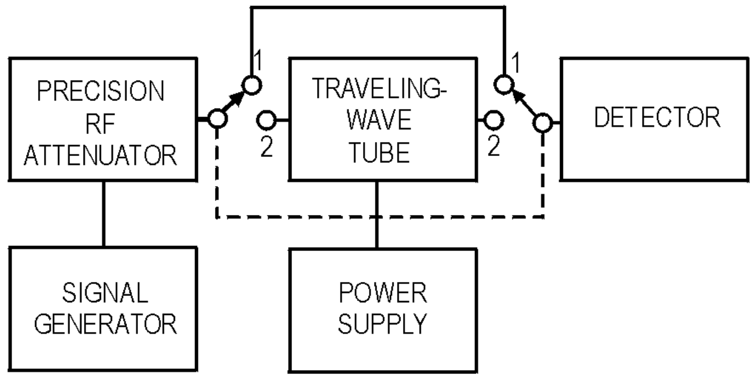

Figure 2-3.—Traveling-wave tube test arrangement.

When you use the twt as an oscillator, failure of the tube to break into oscillations when all other conditions are normal usually indicates a defective tube. In the case of a tube used as a receiving amplifier, an increase of noise with a normal or reduced output can indicate that the tube is failing but is still usable. All the general rules applying to klystron tubes mentioned previously are also applicable to the twt.

Magnetron Tube Tests

You test a magnetron tube while it is in the transmitter equipment in which it is to be used. When you install the magnetron in the transmitter, the condition of the tube can be determined by the normal plate-current measurement and the power, frequency spectrum, and standing-wave-ratio tests of the output signal. An unusual value for any of these measurements may indicate a defective tube.

Crossed-Field Amplifier

You usually test a crossed-field amplifier (cfa) tube while it is in the equipment in which it is used. Like the klystron, if you do not operate the cfa for more than a few months, the tube may become gassy. If a cfa tube is suspected of being gassy, we recommend that you consult the technical manual for the particular piece of equipment in which the crossed-field amplifier is used.

TESTING SEMICONDUCTORS

Unlike vacuum tubes, transistors are very rugged in that they can tolerate vibration and a rather large degree of shock. Under normal operating conditions, they will provide dependable operation for a long period of time. However, transistors are subject to failure when they are subjected to relatively minor overloads. Crystal detectors are also subject to failure or deterioration when subjected to electrical overloads and will deteriorate from a long period of normal use. To determine the condition of semiconductors, you can use various test methods. In many cases you may substitute a transistor of known good quality for a questionable one to determine the condition of a suspected transistor. This method is highly accurate and sometimes efficient. However, you should avoid indiscriminate substitution of semiconductors in critical circuits. When transistors are soldered into equipment, substitution becomes impractical - generally, you should test these transistors while they are in their circuits.

Q-7. What is the major advantage of a transistor over a tube?

Since certain fundamental characteristics indicate the condition of semiconductors, test equipment is available that allows you to test these characteristics with the semiconductors in or out of their circuits. Crystal-rectifier testers normally allow you to test only the forward-to-reverse current ratio of the crystal. Transistor testers, however, allow you to measure several characteristics, such as the collector leakage current ($_{Ic}$), collector to base current gain (β), and the four-terminal network parameters. The most useful test characteristic is determined by the type of circuit in which the transistor will be used. Thus, the alternating-current beta measurement is preferred for ac amplifier or oscillator applications; and for switching-circuit applications, a direct-current beta measurement may prove more useful.

Many common transistors are extremely heat sensitive. Excess heat will cause the semiconductor to either fail or give intermittent operation. You have probably experienced intermittent equipment problems and know them to be both time consuming and frustrating. You know, for example, that if a problem is in fact caused by heat, simply opening the equipment during the course of troubleshooting may cause the problem to disappear. You can generally isolate the problem to the faulty printed-circuit board (pcb) by observing the fault indications. However, to further isolate the problem to a faulty component, sometimes you must apply a minimal amount of heat to the suspect pcb by carefully using a low wattage, heat shrink gun; an incandescent drop light; or a similar heating device. Be careful not to overheat the pcb. Once the fault indication reappears, you can isolate the faulty component by spraying those components suspected as being bad with a nonconductive circuit coolant, such as Freon. If the alternate heating and cooling of a component causes it to operate intermittently, you should replace it.

Q-8. Name two major disadvantages of transistors.

TRANSISTOR TESTING

When trouble occurs in solid-state equipment, you should first check power supplies and perform voltage measurements, waveform checks, signal substitution, or signal tracing. If you isolate a faulty stage by one of these test methods, then voltage, resistance, and current measurements can be made to locate defective parts. When you make these measurements, the voltmeter impedance must be high enough that it exerts no appreciable effect upon the voltage being measured. Also, current from the ohmmeter you use must not damage the transistors. If the transistors are not soldered into the equipment, you should remove the transistors from the sockets during a resistance test. Transistors should be removed from or reinserted into the sockets only after power has been removed from the stage; otherwise damage by surge currents may result.

Transistor circuits, other than pulse and power amplifier stages, are usually biased so that the emitter current is from 0.5 milliampere to 3 milliamperes and the collector voltage is from 3 to 15 volts. You can measure the emitter current by opening the emitter connector and inserting a milliammeter in series. When you make this measurement, you should expect some change in bias because of the meter resistance. You can often determine the collector current by measuring the voltage drop across a resistor in the collector circuit and calculating the current. If the transistor itself is suspected, it can be tested by one or more of the methods described below.

Resistance Test

You can use an ohmmeter to test transistors by measuring the emitter-collector, base-emitter, and base-collector forward and reverse resistances. A back-to-forward resistance ratio on the order of 100 to 1 or greater should be obtained for the collector-to-base and emitter-to-base measurements. The forward and reverse resistances between the emitter and collector should be nearly equal. You should make all three measurements for each transistor you test, because experience has shown that transistors can develop shorts between the collector and emitter and still have good forward and reverse resistances for the other two measurements. Because of shunting resistances in transistor circuits, you will normally have to disconnect at least two transistor leads from the associated circuit for this test. Exercise caution during this test to make certain that current during the forward resistance tests does not exceed the rating of the transistor — ohmmeter ranges requiring a current of more than 1 milliampere should not be used for testing transistors. Many ohmmeters are designed such that on the $R \times 1$ range, 100 milliamperes or more can flow through the electronic part under test. For this reason, you should use a digital multimeter. Be sure you select a digital multimeter that produces enough voltage to properly bias the transistor junctions.

Q-9. When you are using an ohmmeter to test a transistor, what range settings should be avoided?

Transistor Testers

Laboratory transistor test sets are used in experimental work to test all characteristics of transistors. For maintenance and repair, however, it is not necessary to check all of the transistor parameters. A check of two or three performance characteristics is usually sufficient to determine whether a transistor needs to be replaced. Two of the most important parameters used for transistor testing are the transistor current gain (beta) and the collector leakage or reverse current (I_c).

The semiconductor test set (fig. 2-4) is a rugged, field type of tester designed to test transistors and semiconductor diodes. The set measures the beta of a transistor, resistance appearing at the electrodes, reverse current of a transistor or semiconductor diode, shorted or open conditions of a diode, forward transconductance of a field-effect transistor, and condition of its own batteries.

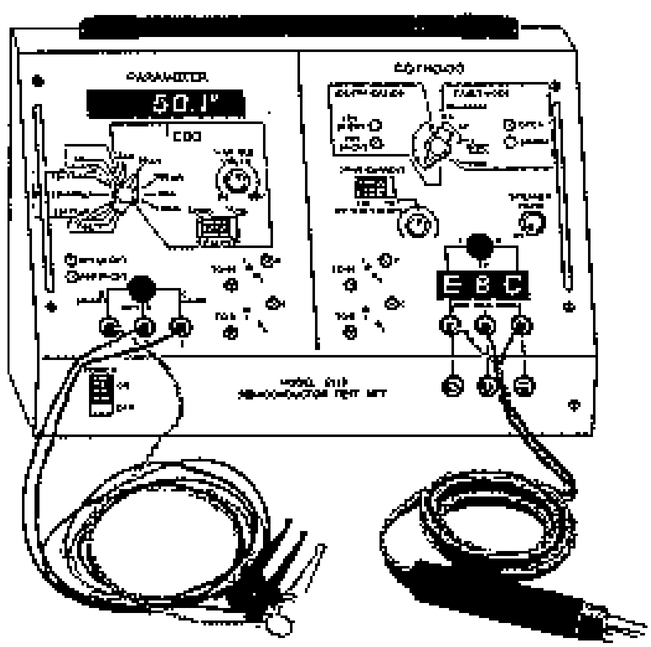

Figure 2-4.—Semiconductor test set.

In order to assure that accurate and useful information is gained from the transistor tester, the following preliminary checks of the tester should be made prior to testing any transistors.

With the POLARITY switch (fig. 2-4) in the OFF position, the meter pointer should indicate exactly zero. (When required, rotate the meter adjust screw on the front of the meter to fulfill this requirement.) When measurements are not actually being made, the POLARITY switch must always be left in the OFF position to prevent battery drain.

Always check the condition of the test set batteries by disconnecting the test set power cord, placing the POLARITY switch in the PNP position and placing the FUNCTION switch first to BAT.1, then to BAT.2. In both BAT positions the meter pointer should move so as to indicate within the red BAT range.

BETA MEASUREMENTS.—If the transistor is to be tested out of the circuit, plug it into the test jack located on the right-hand side below the meter shown in figure 2-4. If the transistor is to be tested in the circuit, it is imperative that at least 300 ohms exist between E-B, C-B, and C-E for accurate measurement. Initial settings of the test set controls are as follows:

1. FUNCTION switch to BETA
2. POLARITY switch to PNP or NPN (dependent on type of transistor under test)
3. RANGE switch to X10
4. Adjust METER ZERO for zero meter indication (transistor disconnected)

NOTE: The POLARITY switch should remain OFF while the transistor is connected to or disconnected from the test set. If you determine that the beta reading is less than 10, reset the RANGE switch to X1 and reset the meter to zero.

After connecting the yellow test lead to the emitter, the green test lead to the base, and the blue test lead to the collector, plug the test probe (not shown) into the jack located at the lower right-hand corner of the test set. When testing grounded equipment, unplug the 115 vac line cord and use battery operation. The beta reading is attained by multiplying the meter reading times the RANGE switch setting. Refer to the transistor characteristics book provided with the tester to determine if the reading is normal for the type of transistor under test.

ELECTRODE RESISTANCE MEASUREMENTS.—Connect the in-circuit probe test leads to the transistor with the yellow lead to the emitter, the green lead to the base, and the blue lead to the collector. Set the FUNCTION switch to the OHMS E-B position, and read the resistance between the emitter and base electrode on the center scale of the meter.

To read the resistance between the collector and base and the collector and emitter, set the FUNCTION switch to OHMS C-B and OHMS C-E. These in-circuit electrode resistance measurements are used to correctly interpret the in-circuit beta measurements. The accuracy of the BETA X1, X10 range is ±15 percent only when the emitter-to-base load is equal to or greater than 300 ohms.

I_c MEASUREMENTS.—Adjust the METER ZERO control for zero meter indication. Plug the transistor to be tested into the jack or connect test leads to the device under test. Set the PNP/NPN switch to correspond with the transistor under test. Set the FUNCTION switch to I_c and the RANGE switch to X0.1, X1, or X10 as specified by the transistor data book for allowable leakage. Read the amount of leakage on the bottom scale, and multiply this by the range setting figure as required.

DIODE MEASUREMENTS.—Diode qualitative in-circuit measurements are attained by connecting the green test lead to the cathode and the yellow test lead to the anode. Set the FUNCTION switch to DIODE IN/CKT and the RANGE switch to X1. (Ensure that the meter has been properly zeroed on this scale.) If the meter reads down scale, reverse the POLARITY switch. If the meter reads less than midscale, the diode under test is either open or shorted. The related circuit impedance of this test is less than 25 ohms.

PRECAUTIONS.—Transistors, although generally more rugged mechanically than electron tubes, are susceptible to damage by excessive heat and electrical overload. The following precautions should be taken in servicing transistorized equipment:

1. Test equipment and soldering irons must be checked to make certain that there is no leakage current from the power source. If leakage current is detected, isolation transformers must be used.
2. Ohmmeter ranges that require a current of more than 1 milliampere in the test circuit are not to be used for testing transistors.
3. Battery eliminators should not be used to furnish power for transistor equipment because they have poor voltage regulation and, possibly, high ripple voltage.
4. The heat applied to a transistor, when soldered connections are required, should be kept to a minimum by using a low-wattage soldering iron and heat shunts (such as long-nose pliers) on the transistor leads.
5. All circuits should be checked for defects before a transistor is replaced.
6. The power should be removed from the equipment before replacing a transistor or other circuit part.
7. When working on equipment with closely spaced parts, you will find that conventional test probes are often the cause of accidental short circuits between adjacent terminals. Momentary short circuits, which rarely cause damage to an electron tube, may ruin a transistor. To avoid accidental shorts, a test probe can be covered with insulation for all but a very short length of the tip.

Electrostatic Discharge Sensitive (ESDS) Care

Devices that are sensitive to electrostatic discharge (ESD) require special handling. You can readily identify ESD-sensitive (ESDS) devices by the symbols shown in figure 2-5. Static electricity is created whenever two substances (solid or fluid) are rubbed together or separated. The rubbing or separating of substances causes the transfer of electrons from one substance to the other; one substance then becomes positively charged, and the other becomes negatively charged. When either of these charged substances comes in contact with a grounded conductor, an electrical current flows until that substance is at the same electrical potential as ground.

Figure 2-5.—Warning symbols for ESDS devices.

You commonly experience static build-up during the winter months when you walk across a vinyl or carpeted floor. (Synthetics, especially plastics, are excellent generators of static electricity.) If you then touch a doorknob or any other conductor, an electrical arc to ground may result, and you may receive a slight shock. For you to experience such a shock, the electrostatic potential created must be 3,500 to 4,000 volts. Lesser voltages, although present and similarly discharged, normally are not apparent to your nervous system. Some typical measured static charges caused by various actions are shown in table 2-1.

Table 2-1.—Typical Measured Static Charges (in volts)

ITEM	RELATIVE HUMIDITY	
	LOW (10 - 20%)	HIGH (65 - 90%)
WALKING ACROSS CARPET	35,000V	1,500V
WALKING OVER VINYL FLOOR	12,000V	250V
WORKER AT BENCH	6,000V	100V
VINYL ENVELOPES FOR WORK INSTRUCT.	7,000V	600V
POLY BAG PICKED UP FROM BENCH	20,000V	1,200V
WORK CHAIR PADDED WITH URETHANE FORM	18,000 V	1,500 V

Q-10. At approximately what minimum voltage potential should you be able to feel an electrostatic discharge?

Metal oxide semiconductor (MOS) devices are the most susceptible to damage from ESD. For example, an MOS field-effect transistor (MOSFET) can be damaged by a static voltage potential of as little as 35 volts. Commonly used discrete bipolar transistors and diodes (often used in ESD-protective circuits), although less susceptible to ESD, can be damaged by voltage potentials of less than 3,000 electrostatic volts. Damage does not always result in sudden device failure but sometimes results in device degradation and early failure. Table 2-1 clearly shows that electrostatic voltages well in excess of

3,000 volts can be easily generated, especially under low-humidity conditions. ESD damage of ESDS parts or circuit assemblies is possible whenever two or more pins of any of these devices are electrically exposed or have low impedance paths. Similarly, an ESDS device in a printed-circuit board or even in another pcb that is electrically connected in a series can be damaged if it provides a path to ground. ESD damage can occur during the manufacture of equipment or during the servicing of the equipment. Damage can occur anytime devices or assemblies are handled, replaced, tested, or inserted into a connector.

Q-11. A MOSFET can be damaged by an electrostatic discharge at approximately what minimum potential?

ESD-sensitive devices can be grouped by their sensitivity to ESD. Semiconductors fall within the following categories:

- VERY SENSITIVE DEVICES. These include MOS and CMOS devices without input diode protection circuitry on all input circuits; dielectrically isolated semiconductors with internal capacitor contacts connected to external pins; and microcircuits using N + guard-ring construction (with metalization crossing over the guard ring).

- SENSITIVE DEVICES. These include all low-power Schottky-barrier and Schottky-TTL devices; all ECL devices; high input-impedance linear microcircuits; all small-signal transistors that operate at 500 MHz or higher; all discrete semiconductors that use silicon dioxide to insulate metal paths over other active areas; MOS or CMOS devices with input diode protection on all input terminals; junction field-effect transistors; and precision resistive networks.

- MODERATELY SENSITIVE DEVICES. These include all microcircuits and small-signal discrete semiconductors with less than 10 watts dissipation at 25º C, and thick-film resistors.

The following procedure is an example of some of the protective measures used to prevent ESD damage:

1. Before servicing equipment, you should be grounded to discharge any static electricity from your body. This can be accomplished with the use of a test lead (a single-wire conductor with a series resistance of 1 megohm) equipped with alligator clips on each end. After the equipment has been completely de-energized, one clip end is connected to the grounded equipment frame; the other clip end is touched with your bare hand. Figure 2-6 shows a more refined ground strap, which frees both hands for work.

NOTE: When wearing a wrist strap, you should *never use ac-powered test equipment* because of your increased chance of receiving an electrical shock.

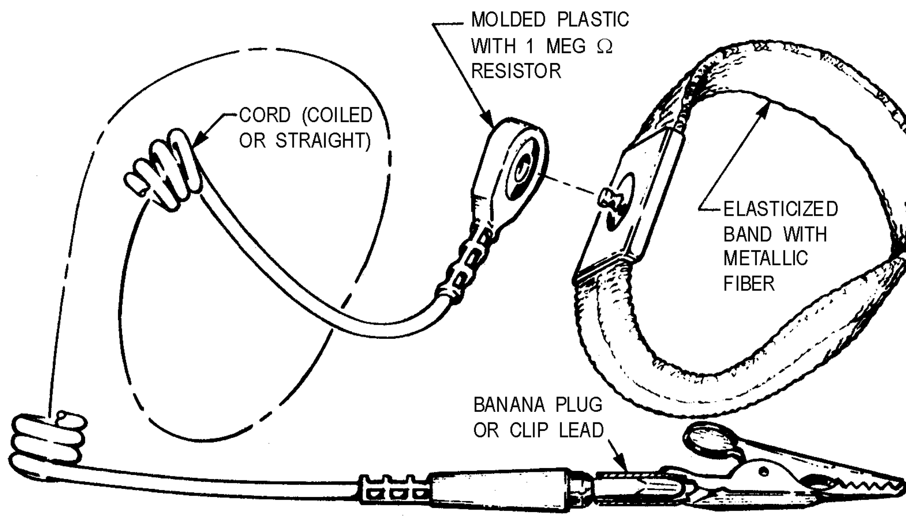

Figure 2-6.—ESD wrist strap.

2. Equipment technical manuals and packaging material should be checked for ESD warnings and instructions.

3. Prior to opening an electrostatic unit package of an ESDS device or assembly, clip the free end of the grounded test lead to the package. This will cause any static electricity that may have built up on the package to discharge. The other end remains connected to the equipment frame or other ESD ground. Keep the unit package grounded until the replacement device or assembly is placed in the unit package.

4. Minimize handling of ESDS devices and assemblies. Keep replacement devices or assemblies, with their connector-shorting bars, clips, and so forth, intact in their electrostatic-free packages until needed. Place removed repairable ESDS devices or assemblies, with their connector shorting bars or clips installed, in electrostatic-free packages as soon as they are removed from the equipment. ESDS devices or assemblies should be transported and stored only in protective packaging.

5. Always avoid unnecessary physical movement, such as scuffing the feet, when handling ESDS devices or assemblies. Such movement will generate additional charges of static electricity.

6. When removing or replacing an ESDS device or assembly in the equipment, hold the device or assembly through the electrostatic-free wrap if possible. Otherwise, pick up the device or assembly by its body only. DO NOT TOUCH component leads, connector pins, or any other electrical connections or paths on boards, even though they are covered by conformal coating.

7. Do not permit ESDS devices or assemblies to come in contact with clothing or other ungrounded materials that could have an electrostatic charge. The charges on a nonconducting material are not equal. A plastic storage bag may have a −10,000 volt potential one-half inch from a +15,000 volt potential, with many other such charges all over the bag. Placing a circuit card inside the bag allows the charges to equalize through the pcb conductive paths and components, thereby causing failures. Do not hand an ESDS device or assembly to another person until the device or assembly is protectively packaged.

8. When moving an ESDS device or assembly, always touch (with your bare skin) the surface on which it rests for at least 1 second before picking it up. Before placing it on any surface, touch the

surface with your free hand for at least 1 second. The bare skin contact provides a safe discharge path for electrostatic charges accumulated while you are moving around.

9. While servicing equipment containing ESDS devices, do not handle or touch materials such as plastic, vinyl, synthetic textiles, polished wood, fiber glass, or similar items that could create static charges; or, be sure to repeat the grounding action with the bare hands after contacting these materials. These materials are prime electrostatic generators.

10. If possible, avoid repairs that require soldering at the equipment level. Soldering irons must have heater and tip assemblies grounded to ac electrical ground. Do not use ordinary plastic solder suckers (special antistatic solder suckers are commercially available).

11. Ground the leads of test equipment momentarily before you energize the test equipment and before you probe ESDS items.

Q-12. Why should you avoid using ac-powered test equipment when wearing a wrist strap?

DIODE TESTING

Because of the reliability of semiconductor devices, servicing techniques developed for transistorized equipment differ from those used for electron-tube circuits. Electron tubes are usually considered to be the circuit component most susceptible to failure and are normally the first to be tested. Transistors, however, are capable of operating in excess of 30,000 hours at maximum ratings without appreciable degradation. They are often soldered into equipment in the same manner as resistors and capacitors. Substitution of a diode or transistor known to be in good condition is a simple method of determining the quality of a questionable semiconductor device. You should use this technique only after voltage and resistance measurements indicate that no circuit defect exists that might damage the substituted semiconductor device. If more than one defective semiconductor is present in the equipment section where trouble has been localized, substitution becomes cumbersome since several semiconductors may have to be replaced before the trouble is corrected. To determine which stages failed and which semiconductors are not defective, you must test all of the removed semiconductors. This can be accomplished by observing whether the equipment operates correctly as each of the removed semiconductor devices is reinserted into the equipment.

Q-13. Prior to substituting a diode, what measurements should you take to determine its condition?

DIODE TESTERS

Diodes, such as general-purpose germanium and silicon diodes, power silicon diodes, and microwave silicon diodes, are most effectively tested under actual operating conditions. However, rectifier testers are available for you to determine direct-current characteristics that provide an indication of diode quality.

Rf Diode Test

A common type of diode test set is a combination ohmmeter-ammeter. You can make measurements of forward resistance, back resistance, and reverse current with this equipment. You can determine the condition of the rectifier under test by comparing its actual values with typical values obtained from test information furnished with the test set or from the manufacturer’s data sheets. Comparing the diode’s back and forward resistance at a specified voltage provides you with a rough indication of the rectifying property of a diode. A typical back-to-forward resistance ratio is on the order of 10 to 1, and a forward-resistance value of 50 to 80 ohms is common.

Switching Diode Test

To effectively test diodes used for computer applications, you must obtain back-resistance measurements at a large number of different voltage levels. This can be done efficiently by using a dynamic diode tester in conjunction with an oscilloscope, which is used to display the diode's back-current-versus-voltage curve. You can easily interpret diode characteristics, such as flutter, hysteresis, and negative resistance, through use of the dynamic current and voltage display.

DIODE CHARACTERISTIC GRAPHICAL DISPLAY

You can use an oscilloscope to graphically display the forward- and back-resistance characteristics of a diode. A test circuit used in conjunction with an oscilloscope is shown in figure 2-7. This circuit uses an audio-signal generator as the test signal. It should be adjusted for an approximate 2-volt, 60-hertz signal, as measured across R1.

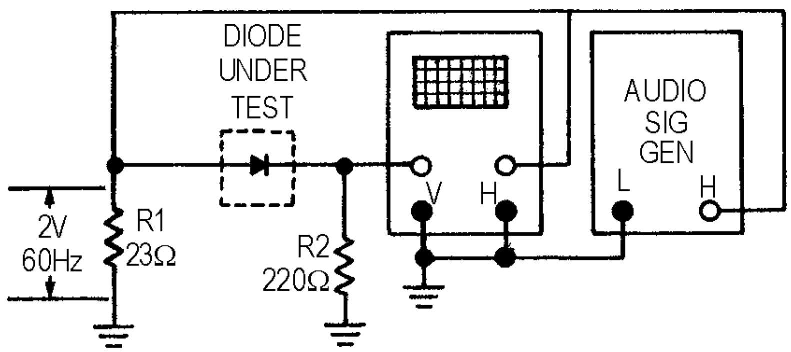

Figure 2-7.—Display circuit used with an oscilloscope.

The test signal you apply to the diode is also connected to the horizontal input of the oscilloscope. The horizontal sweep will then display the voltage applied to the diode under test. The voltage developed across current-measuring resistor R2 is applied to the vertical input of the oscilloscope. Since this voltage is proportional to the current through the diode under test, the vertical deflection will indicate diode current. The resulting oscilloscope trace will be similar to the curve shown in figure 2-8.

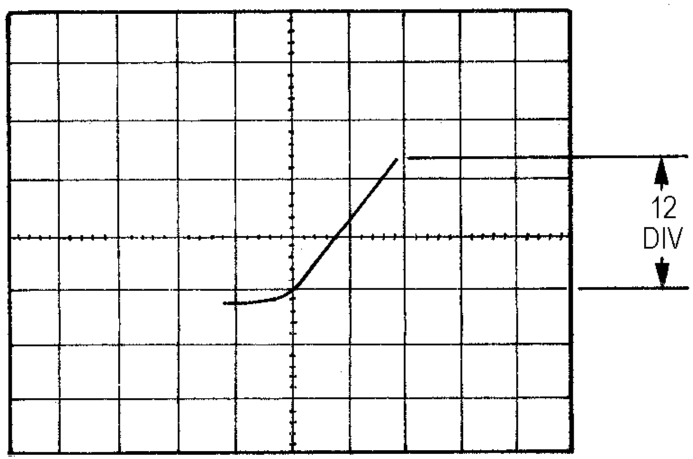

Figure 2-8.—Typical characteristic curve of a silicone diode.

Reverse Voltage-Current Analysis

You can make an analysis of the reverse voltage-current portion of the characteristic curve for a diode with the method described above or with a diode test set. This test is very important for diodes used in computer applications, where stability of operation is essential. Various diode conditions that may be detected by this test are shown in figure 2-9, view A, view B, view C, and view D.

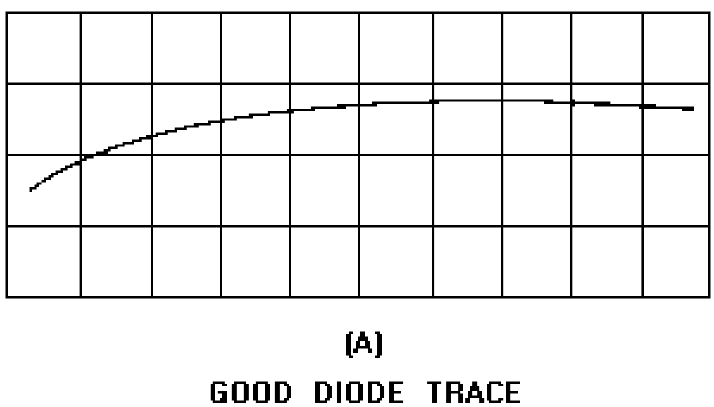

Figure 2-9A.—Diode reverse current-voltage characteristics. GOOD DIODE TRACE.

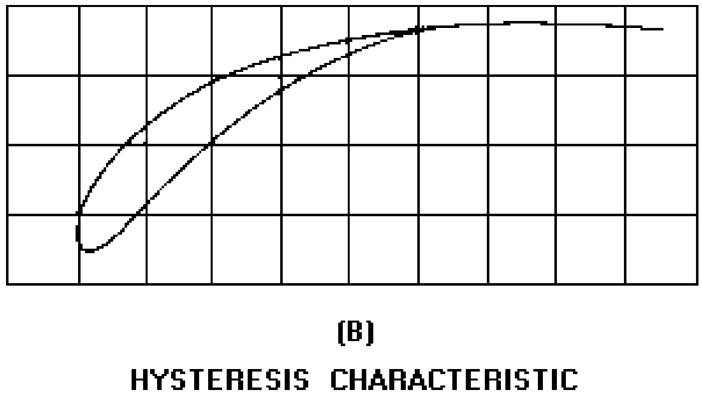

Figure 2-9B.—Diode reverse current-voltage characteristics. HYSTERESIS CHARACTERISTIC.

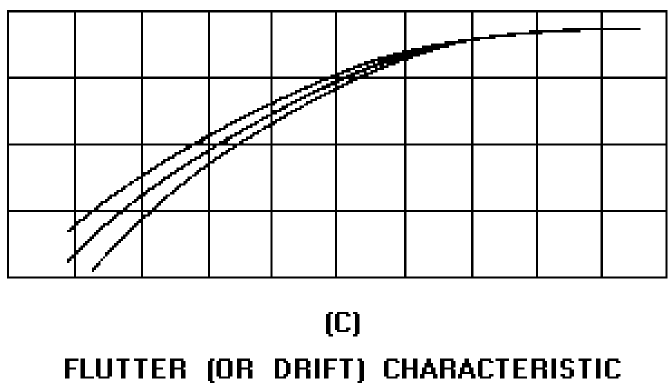

Figure 2-9C.—Diode reverse current-voltage characteristics. FLUTTER (OR DRIFT) CHARACTERISTIC.

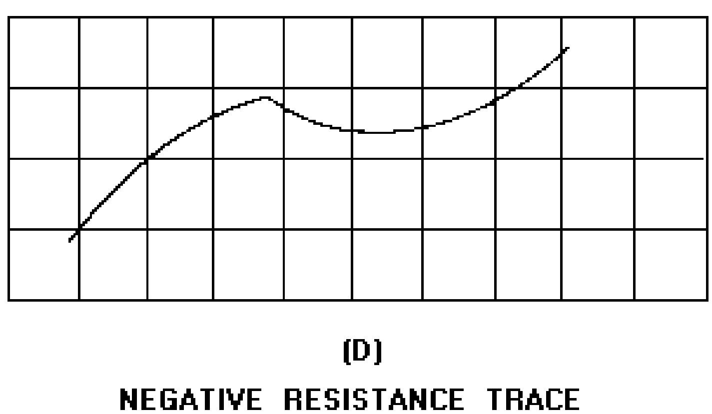

Figure 2-9D.—Diode reverse current-voltage characteristics. NEGATIVE RESISTANCE TRACE.

Zener Diode Test

An audio signal generator may not be able to produce a high enough voltage for you to test Zener diodes. You can, however, make this test with a diode test set or with the circuit shown in figure 2-10. In this circuit, R1 is used to adjust the input voltage to a suitable value for the Zener diode being tested. Resistor R2 limits the current through the diode. The signal voltage applied to the diode is also connected to the horizontal input of the oscilloscope. The voltage developed across current-measuring resistor R3 is applied to the vertical input of the oscilloscope. The horizontal sweep will therefore represent the applied voltage, and the vertical deflection will indicate the current through the diode under test. Figure 2-11 shows the characteristic pattern of a Zener diode (note the sharp increase in current at the avalanche breakdown point). For the Zener diode to be acceptable, this voltage must be within the limits specified by the manufacturer.

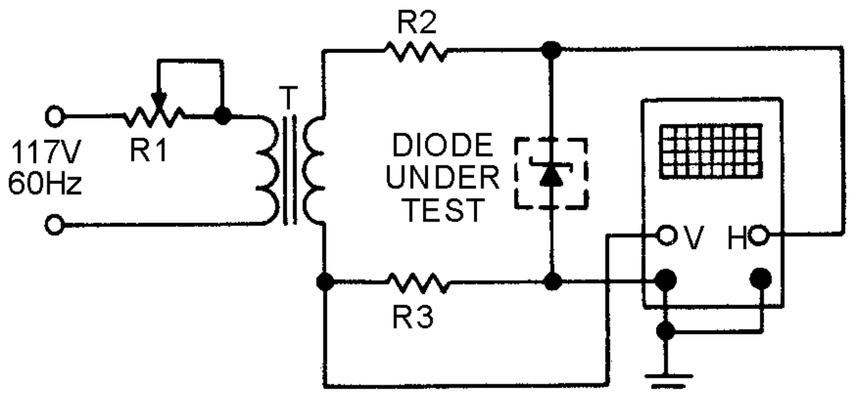

Figure 2-10.—Zener diode test circuit.

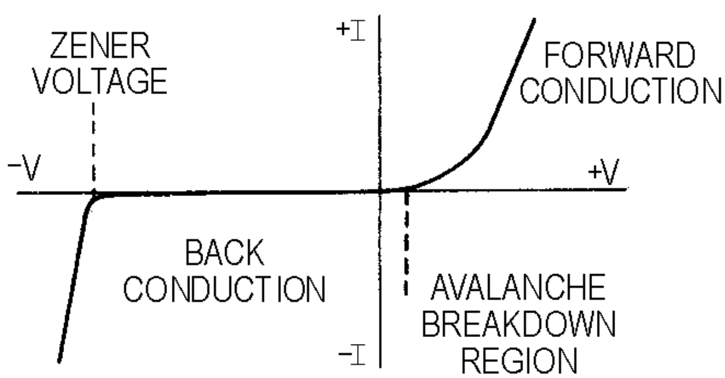

Figure 2-11.—Zener diode characteristic pattern.

STATIC RESISTANCE MEASUREMENTS

One convenient method of testing a diode requires only your ohmmeter. The forward and back resistances can be measured at a voltage determined by the battery potential of the ohmmeter and the resistance range at which the meter is set. When the test leads of the ohmmeter are connected to the diode, a resistance will be measured that is different from the resistance indicated if the leads are reversed. The smaller value is called the forward resistance, and the larger value is called the back resistance. If the ratio of back-to-forward resistance is greater than 10 to 1, the diode should be capable of functioning as a rectifier. This is a very limited test, which does not take into account the action of the diode at voltages of different magnitudes and frequencies. Some diodes may be damaged by the excessive current produced by some range settings of a standard multimeter. Therefore, you should use a digital multimeter when performing this measurement.

Q-14. As a rule of thumb, what is an acceptable ratio of back-to-forward resistance for a diode?

SILICON-CONTROLLED RECTIFIERS (SCR)

Many naval electronic equipments use silicon-controlled rectifiers (SCRs) for the control of power. Like other solid-state components, SCRs are subject to failure. You can test most SCRs with a standard ohmmeter, but you must understand just how the SCR functions.

As shown in figure 2-12, the SCR is a three-element, solid-state device in which the forward resistance can be controlled. The three active elements shown in the figure are the anode, cathode, and gate. Although they may differ in outward appearance, all SCRs operate in the same way. The SCR acts like a very high-resistance rectifier in both forward and reverse directions without requiring a gate signal. However, when the correct gate signal is applied, the SCR conducts only in the forward direction, the same as any conventional rectifier. To test an SCR, you connect an ohmmeter between the anode and cathode, as shown in figure 2-12. Start the test at $R \times 10{,}000$ and reduce the value gradually. The SCR under test should show a very high resistance, regardless of the ohmmeter polarity. The anode, which is connected to the positive lead of the ohmmeter, must now be shorted to the gate. This will cause the SCR to conduct; as a result, a low-resistance reading will be indicated on the ohmmeter. Removing the anode-to-gate short will not stop the SCR from conducting; but removing either of the ohmmeter leads will cause the SCR to stop conducting — the resistance reading will then return to its previous high value. Some SCRs will not operate when you connect an ohmmeter. This is because the ohmmeter does not supply enough current. However, most of the SCRs in Navy equipment can be tested by the ohmmeter method. If an SCR is sensitive, the $R \times 1$ scale may supply too much current to the device and damage it. Therefore, try testing it on the higher resistance scales.

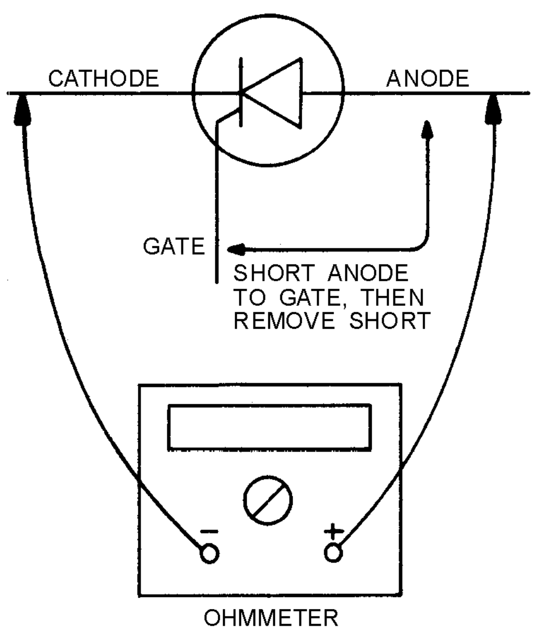

Figure 2-12.—Testing an SCR with an ohmmeter.

Q-15. When testing an SCR with an ohmmeter, the SCR will conduct if what two elements are shorted together?

TRIAC

Triac is General Electric's trade name for a silicon, gate-controlled, full-wave, ac switch, as shown in figure 2-13. The device is designed to switch from a blocking state to a conducting state for either polarity of applied voltages and with either positive or negative gate triggering. Like a conventional SCR, the Triac is an excellent solid-state device for controlling current flow. You can make the Triac conduct by using the same method used for an SCR, but the Triac has the advantage of being able to conduct equally well in either the forward or reverse direction.

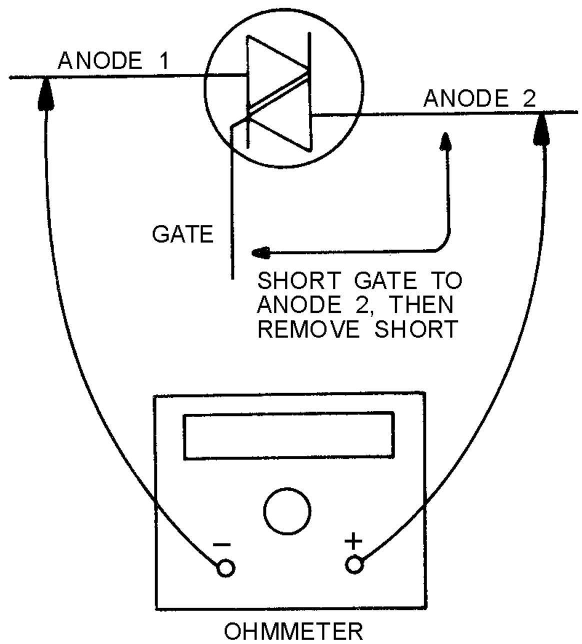

Figure 2-13.—Testing a Triac with an ohmmeter.

To test the Triac with an ohmmeter (R × 1 scale), you connect the ohmmeter's negative lead to anode 1 and the positive lead to anode 2, as shown in figure 2-13. The ohmmeter should indicate a very high resistance. Short the gate to anode 2; then remove it. The resistance reading should drop to a low value and remain low until either of the ohmmeter leads is disconnected from the Triac. This completes the first test.

The second test involves reversing the ohmmeter leads between anodes 1 and 2 so that the positive lead is connected to anode 1 and the negative lead is connected to anode 2. Again, short the gate to anode 2; then remove it. The resistance reading should again drop to a low value and remain low until either of the ohmmeter leads is disconnected.

Q-16. When a Triac is properly gated, what is/are the direction(s) of current flow between anodes 1 and 2?

UNIJUNCTION TRANSISTORS (UJTs)

The unijunction transistor (UJT), shown in figure 2-14, is a solid-state, three-terminal semiconductor that exhibits stable open-circuit, negative-resistance characteristics. These characteristics enable the UJT to serve as an excellent oscillator. Testing a UJT is a relatively easy task if you view the UJT as being a diode connected to the junction of two resistors, as shown in figure 2-15. With an ohmmeter, measure the resistance between base 1 and base 2; then reverse the ohmmeter leads and take another reading. Readings should show the same high resistance regardless of meter lead polarity. Connect the negative lead of the ohmmeter to the emitter of the UJT. Using the positive lead, measure the resistance from the emitter to base 1 and then from the emitter to base 2. Both readings should indicate high resistances that are approximately equal to each other. Disconnect the negative lead from the emitter and connect the positive lead to it. Using the negative lead, measure the resistance from the emitter to base 1 and then from the emitter to base 2. Both readings should indicate low resistances approximately equal to each other.

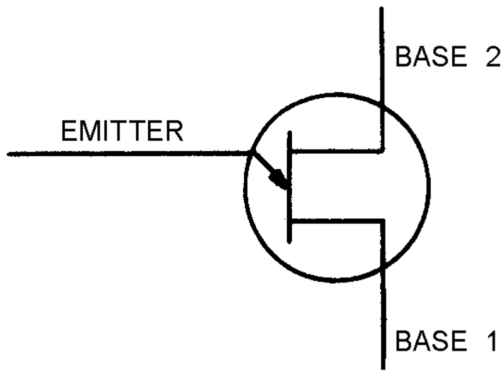

Figure 2-14.—Unijunction transistor.

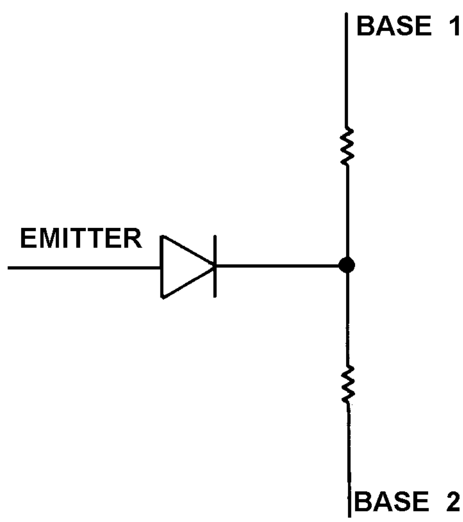

Figure 2-15.—Unijunction transistor equivalent circuit.

JUNCTION FIELD-EFFECT TRANSISTOR (JFET) TESTS

The junction field-effect transistor (JFET) has circuit applications similar to those of a vacuum tube. The JFET has a voltage-responsive characteristic with a high input impedance. Two types of JFETs that you should become familiar with are the junction p-channel and the junction n-channel types, as shown in figure 2-16. Their equivalent circuits are shown in figures 2-17 and 2-18, respectively. The only difference in your testing of these two types of JFETs involves the polarity of the meter leads.

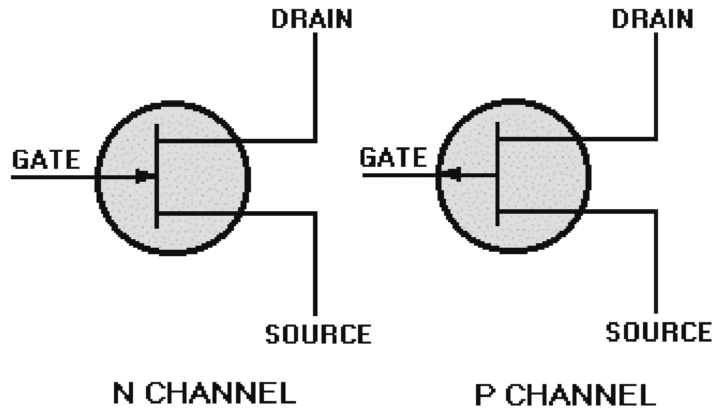

Figure 2-16.—Junction FETs.

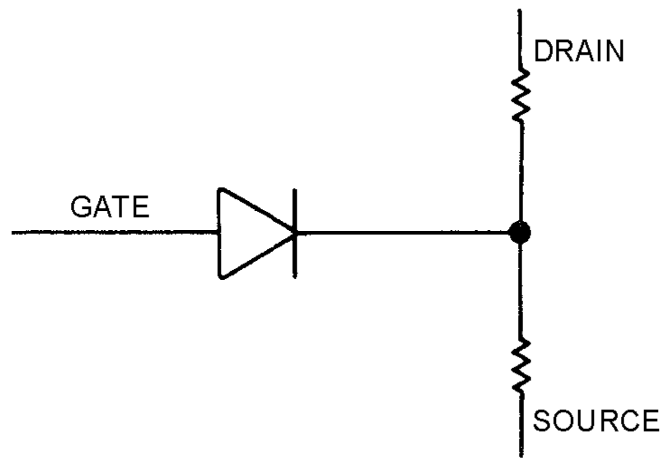

Figure 2-17.—N-channel JFET equivalent circuit.

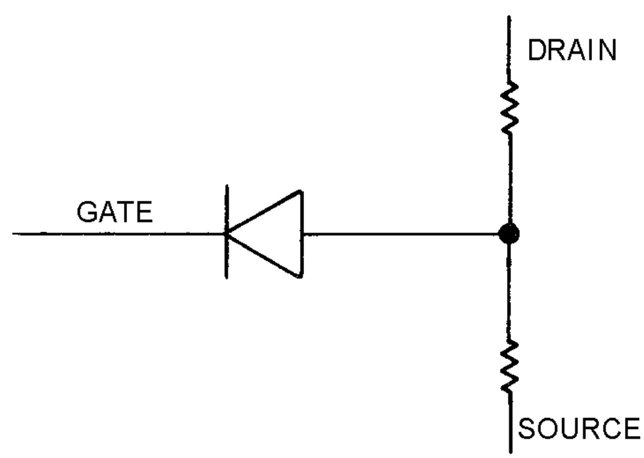

Figure 2-18.—P-channel JFET equivalent circuit.

N-Channel Test

Using an ohmmeter set to the R × 100 scale, measure the resistance between the drain and the source; then reverse the ohmmeter leads and take another reading. Both readings should be equal (in the 100- to 10,000-ohm range), regardless of the meter lead polarity. Connect the positive meter lead to the gate. Using the negative lead, measure the resistance between the gate and the drain; then measure the resistance between the gate and the source. Both readings should indicate a low resistance and be approximately the same. Disconnect the positive lead from the gate and connect the negative lead to the gate. Using the positive lead, measure the resistance between the gate to the drain; then measure the resistance between the gate and the source. Both readings should show infinity.

P-Channel Test

Using an ohmmeter set to the R × 100 scale, measure the resistance between the drain and the source; then reverse the ohmmeter leads and take another reading. Both readings should be the same (100 to 10,000 ohms), regardless of meter lead polarity. Next, connect the positive meter lead to the gate. Using the negative lead, measure the resistance between the gate and the drain; then measure it between the gate and the source. Both readings should show infinity. Disconnect the positive lead from the gate and connect the negative lead to the gate. Using the positive lead, measure the resistance between the gate and the drain; then measure it between the gate and the source. Both readings should indicate a low resistance and be approximately equal.

MOSFET TESTING

Another type of semiconductor you should become familiar with is the metal oxide semiconductor field-effect transistor (MOSFET), as shown in figures 2-19 and 2-20. You must be extremely careful when working with MOSFETs because of their high degree of sensitivity to static voltages. As previously mentioned in this chapter, the soldering iron should be grounded. A metal plate should be placed on the workbench and grounded to the ship's hull through a 250-kilohm to 1-megohm resistor. You should also wear a bracelet with an attached ground strap and ground yourself to the ship's hull through a 250-kilohm to 1-megohm resistor. You should not allow a MOSFET to come into contact with your clothing, plastics, or cellophane-type materials. A vacuum plunger (solder sucker) must not be used because of the high electrostatic charges it can generate. Solder removal by wicking is recommended. It is also good practice to wrap MOSFETs in metal foil when they are out of a circuit. To ensure MOSFET safety under test, use a portable volt-ohm-milliammeter (vom) to make MOSFET resistance measurements. **A vtvm must never be used in testing MOSFETs.** You must be aware that while you are testing a MOSFET, you are grounded to the ship's hull or station's ground. Use of a vtvm would cause a definite safety hazard because of the 115-volt, 60-hertz power input. When the resistance measurements are complete and the MOSFET is properly stored, unground both the plate on the workbench and yourself. You will understand MOSFET testing better if you visualize it as equivalent to a circuit using diodes and resistors, as shown in figures 2-21 and 2-22.

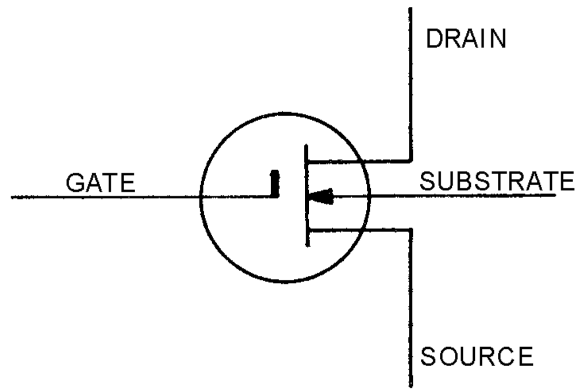

Figure 2-19.—MOSFET (depletion/enhancement type).

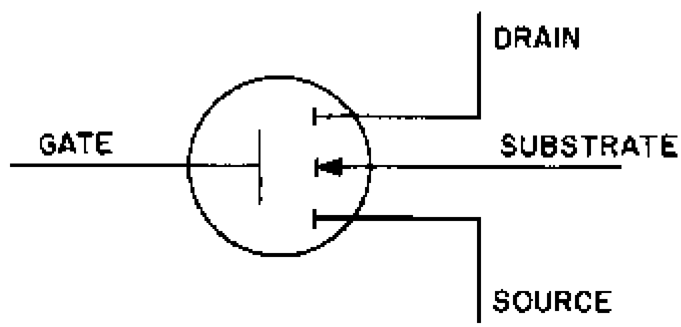

Figure 2-20.—MOSFET (enhancement type).

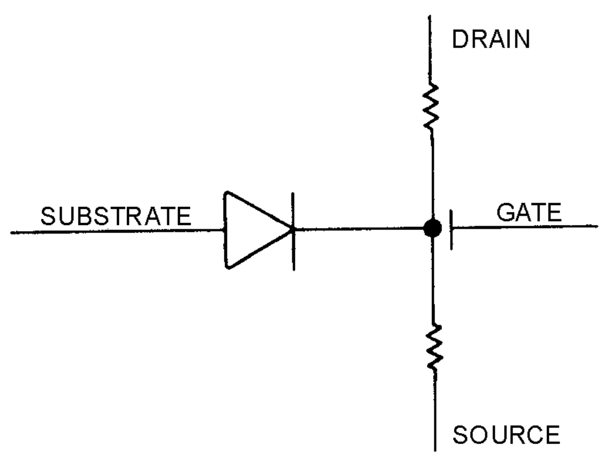

Figure 2-21.—MOSFET (depletion/enhancement type) equivalent circuit.

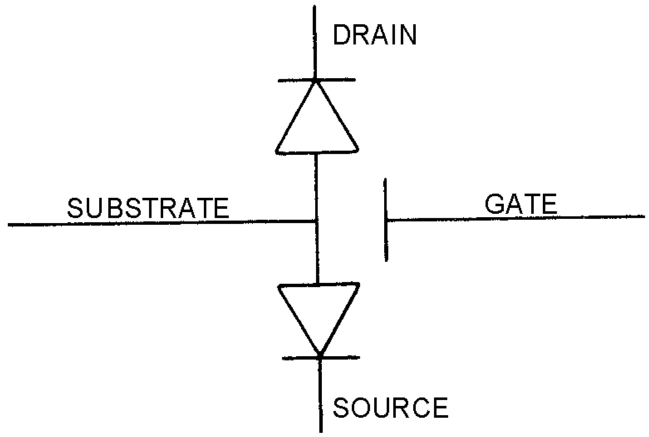

Figure 2-22.—MOSFET (enhancement type) equivalent circuit.

Q-17. Why is it not advisable to use a solder sucker when working on MOSFETs?

MOSFET (Depletion/Enhancement Type) Test

Using an ohmmeter set to the R × 100 scale, measure the resistance between the MOSFET drain and the source; then reverse the ohmmeter leads and take another reading. The readings should be equal, regardless of meter lead polarity. Connect the positive lead of the ohmmeter to the gate. Using the negative lead, measure the resistance between the gate and the drain and between the gate and the source. Both readings should show infinity. Disconnect the positive lead from the gate and connect the negative lead to the gate. Using the positive lead, measure the resistance between the gate and the drain; then measure it between the gate and the source. Both readings should show infinity. Disconnect the negative lead from the gate and connect it to the substrate. Using the positive lead, measure the resistance between the substrate and the drain and between the substrate and the source. Both of these readings should indicate infinity. Disconnect the negative lead from the substrate and connect the positive lead to the substrate. Using the negative lead, measure the resistance between the substrate and the drain and between the substrate and the source. Both readings should indicate a low resistance (about 1,000 ohms).

MOSFET (Enhancement Type) Test

Using an ohmmeter set to the R × 100 scale, measure the resistance between the drain and the source; then reverse the leads and take another reading between the drain and the source. Both readings should show infinity, regardless of meter lead polarity. Connect the positive lead of the ohmmeter to the gate. Using the negative lead, measure the resistance between the gate and the drain and then between the gate and the source. Both readings should indicate infinity. Disconnect the positive lead from the gate and connect the negative lead to the gate. Using the positive lead, measure the resistance between the gate and the drain and then between the gate and the source. Both readings should indicate infinity. Disconnect the negative lead from the gate and connect it to the substrate. Using the positive lead, measure the resistance between the substrate and the drain and between the substrate and the source. Both readings should indicate infinity. Disconnect the negative lead from the substrate and connect the positive lead to the substrate. Using the negative lead, measure the resistance between the substrate and the drain and between the substrate and the source. Both readings should indicate a low resistance (about 1,000 ohms).

INTEGRATED CIRCUIT (IC) TESTING

Integrated circuits (ICs) constitute an area of microelectronics in which many conventional electronic components are combined into high-density modules. Integrated circuits are made up of active and passive components, such as transistors, diodes, resistors, and capacitors. Because of their reduced size, use of integrated circuits can simplify otherwise complex systems by reducing the number of separate components and interconnections. Their use can also reduce power consumption, reduce the overall size of the equipment, and significantly lower the overall cost of the equipment concerned. Many types of integrated circuits are ESDS devices and should be handled accordingly.

Q-18. Name two advantages in using ICs.

Your IC testing approach needs to be somewhat different from that used in testing vacuum tubes and transistors. The physical construction of ICs is the prime reason for this different approach. The most frequently used ICs are manufactured with either 14 or 16 pins, all of which may be soldered directly into the circuit. It can be quite a job for you to unsolder all of these pins, even with the special tools designed for this purpose. After unsoldering all of the pins, you then have the tedious job of cleaning and straightening all of them.

Although there are a few IC testers on the market, their applications are limited. Just as transistors must be removed from the circuit to be tested, some ICs must also be removed to permit testing. When ICs are used in conjunction with external components, the external components should first be checked for proper operation. This is particularly important in linear applications where a change in the feedback of a circuit can adversely affect operating characteristics of the component.

Any linear (analog) IC is sensitive to its supply voltage. This is especially the case among ICs that use bias and control voltages in addition to a supply voltage. If you suspect a linear IC of being defective, all voltages coming to the IC must be checked against the manufacturer's circuit diagram of the equipment for any special notes on voltages. The manufacturer's handbook will also give you recommended voltages for any particular IC.

When troubleshooting ICs (either digital or linear), you cannot be concerned with what is going on inside the IC. You cannot take measurements or conduct repairs inside the IC. You should, therefore, consider the IC as a black box that performs a certain function. You can check the IC, however, to see that it can perform its design functions. After you check static voltages and external components associated with the IC, you can check it for dynamic operation. If it is intended to function as an amplifier, then you can measure and evaluate its input and output. If it is to function as a logic gate or combination of gates, it is relatively easy for you to determine what inputs are required to achieve a desired high or low output. Examples of different types of ICs are provided in figure 2-23.

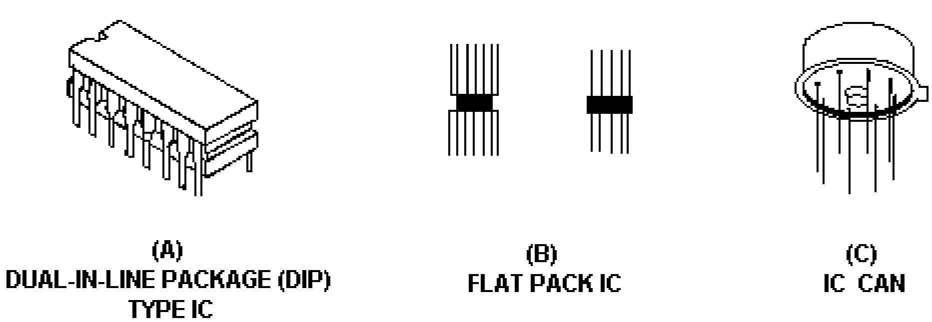

Figure 2-23.—Types of ICs.

Q-19. Why should you consider an IC as a black box?

Digital ICs are relatively easy for you to troubleshoot and test because of the limited numbers of input/output combinations involved. When using positive logic, the logic state of the inputs and outputs of a digital IC can only be represented as either a high (also referred to as a 1 state) or as a low (also referred to as a 0 state). In most digital circuitry, a high is a steady 5-vdc level, and a low is a 0-vdc level. You can readily determine the logic state of an IC by using high-input-impedence measuring devices, such as an oscilloscope. Because of the increased use of ICs in recent years, numerous pieces of test equipment have been designed specifically for testing ICs. They are described in the following paragraphs.

Q-20. What are the two logic states of an IC?

LOGIC CLIPS

Logic clips, as shown in figure 2-24, are spring-loaded devices that are designed to clip onto a dual-in-line package IC while the IC is mounted in its circuit. It is a simple device that usually has 16 light emitting diodes (LEDs) mounted at the top of the clips. The LEDs correspond to the individual pins of the IC, and any lit LED represents a high logic state. An unlit LED represents a low logic state. Logic clips require no external power connections, and they are small and lightweight. Their ability to simultaneously monitor the input and output of an IC is very helpful when you are troubleshooting a logic circuit.

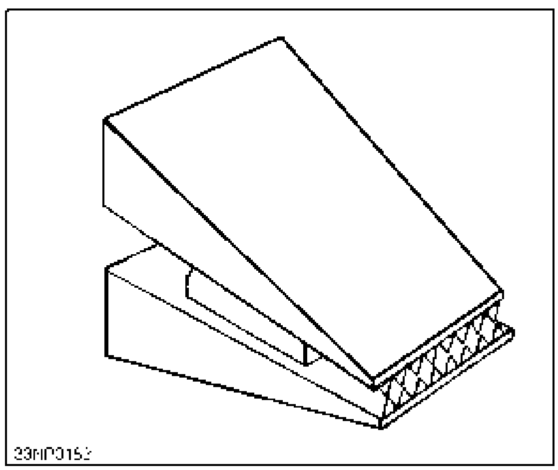

Figure 2-24.—Logic clip.

Q-21. A lighted LED on a logic clip represents what logic level?

LOGIC COMPARATORS

The logic comparator, as shown in figure 2-25, is designed to detect faulty, in-circuit-DIP ICs by comparing them with ICs that are known to be good (reference ICs). The reference IC is mounted on a small printed-circuit board and inserted into the logic comparator. You then attach the logic comparator to the IC under test by a test lead, which is connected to a spring-loaded device similar in appearance to a logic clip. The logic comparator is designed to detect differences in logic states of the reference IC and the IC being tested. If any difference in logic states does exist on any pin, an LED corresponding to the pin in question will be lit on the logic comparator. The logic comparator is powered by the IC under test.

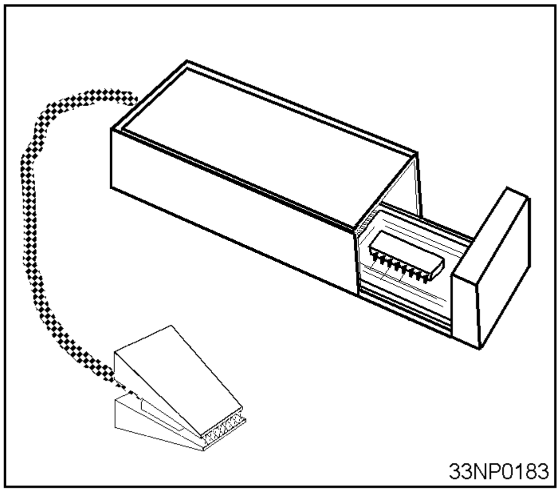

Figure 2-25.—Logic comparator.

Q-22. What does a lighted LED indicate on a logic comparator?

LOGIC PROBES

Logic probes, as shown in figure 2-26, are extremely simple and useful devices that are designed to help you detect the logic state of an IC. Logic probes can show you immediately whether a specific point in the circuit is **low, high, open,** or **pulsing**. A **high** is indicated when the light at the end of the probe is lit and a **low** is indicated when the light is extinguished. Some probes have a feature that detects and displays high-speed transient pulses as small as 5 nanoseconds wide. These probes are usually connected directly to the power supply of the device being tested, although a few also have internal batteries. Since most IC failures show up as a point in the circuit stuck either at a **high** or **low** level, these probes provide a quick, inexpensive way for you to locate the fault. They can also display that single, short-duration pulse that is so hard to catch on an oscilloscope. The ideal logic probe will have the following characteristics:

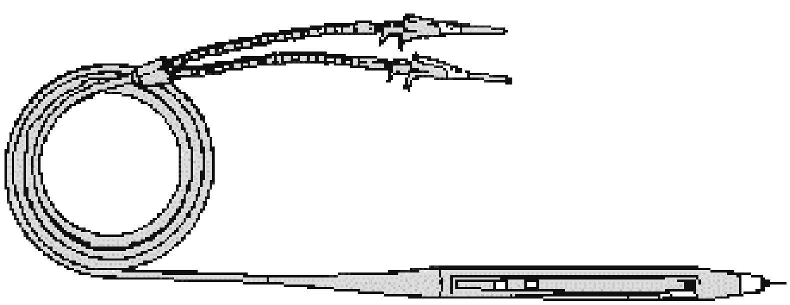

Figure 2-26.—Logic probe.

1. Be able to detect a steady logic level
2. Be able to detect a train of logic levels
3. Be able to detect an open circuit
4. Be able to detect a high-speed transient pulse

5. Have overvoltage protection

6. Be small, light, and easy to handle

7. Have a high input impedance to protect against circuit loading

Q-23. What is the purpose of a logic probe?

LOGIC PULSERS

Another extremely useful device for troubleshooting logic circuits is the logic pulser. It is similar in shape to the logic probe and is designed to inject a logic pulse into the circuit under test. Logic pursers are generally used in conjunction with a logic clip or a logic probe to help you trace the pulse through the circuit under test or verify the proper operation of an IC. Some logic pursers have a feature that allows a single pulse injection or a train of pulses. Logic pursers are usually powered by an external dc power supply but may, in some cases, be connected directly to the power supply of the device under test. View A of figure 2-27 shows a typical logic pulser. View B shows a logic pulser (right) used with a logic probe (left).

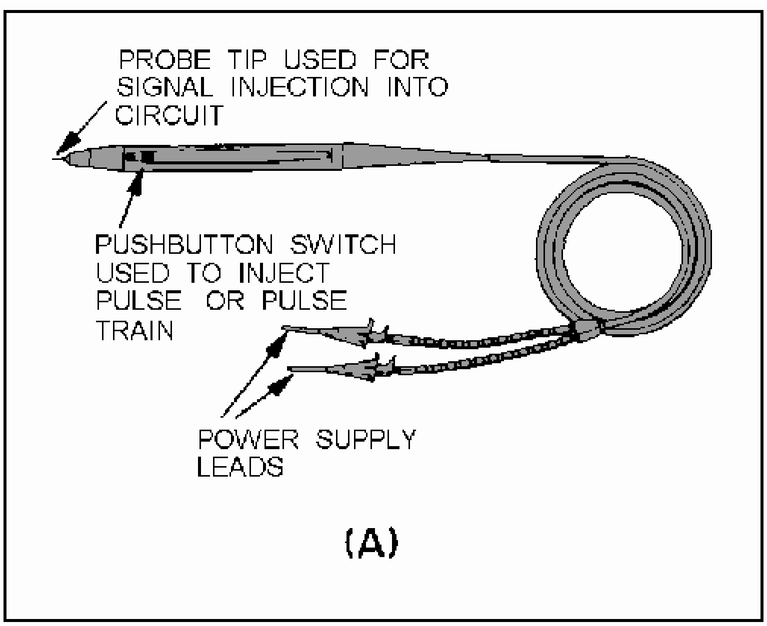

Figure 2-27A.—Logic pulser.

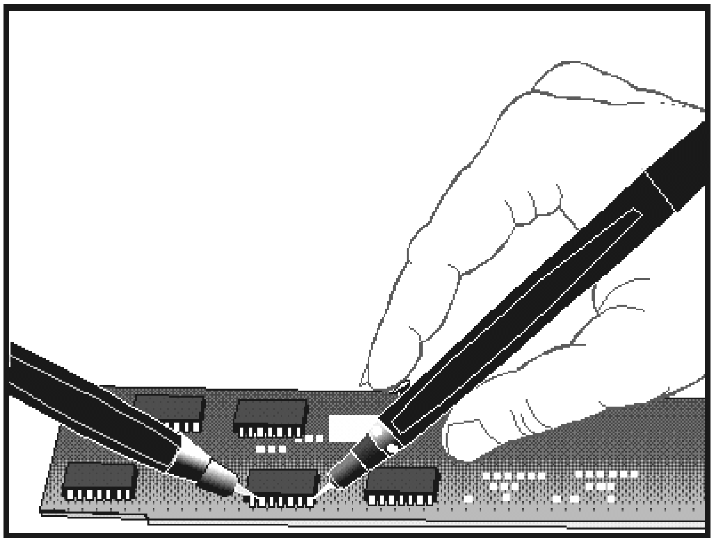

Figure 2-27B.—Logic pulser.

LOGIC ANALYZER

A relatively new device on the test equipment scene is the logic analyzer. A logic analyzer provides various functions that can assist you in maintenance, testing, and troubleshooting of equipment using digital circuitry. From your standpoint, they are extremely useful in performing timing analysis. Most logic analyzers have crt displays that can monitor up to 32 timing signals at the same time. A large percentage of today's digital equipment is designed with the logic analyzer in mind and have built-in status or bus lines for your convenience in monitoring multiple signals at the same time. When monitoring a bus line, you can readily determine, through visual displays, such things as the presence of master clock signals or sequential timing events.

BATTERY MEASUREMENTS

As a technician, you are primarily concerned with the *uses* of batteries; however, checking or testing of storage and dry cell batteries is an important part of your maintenance program. Proper preventive maintenance of batteries can significantly extend the useful life of a battery.

STORAGE BATTERIES

When you check a lead-acid type of storage battery for its condition of charge or discharge, you take a specific gravity reading of the electrolyte by using a hydrometer. A specific gravity reading between 1.275 and 1.300 indicates a full-charge condition and assures you that the battery is in good condition. A hydrometer reading of approximately 1.175 indicates a normal discharge condition, and a reading of approximately 1.250 indicates that the battery is half-discharged. Since the acids used in various batteries do not always have the same specific gravity and since electrode composition may differ, the hydrometer reading you obtain at the charged and discharged conditions will vary with the type of electrolyte and battery composition. A general rule for you to follow is not to discharge a battery more than 100 points (.100 specific gravity) before recharging.

Although readings of specific gravity are a reliable measure of the condition of a storage battery, cells that indicate normal may prove useless under load. This is usually caused by a high internal resistance. A load-voltage check of the cells with the use of a cell tester indicates the actual voltage charge held by each battery cell. Cell voltages should not differ by more than 0.15 volt for 6-volt or 12-volt batteries.

Use extreme caution whenever testing or working around lead-acid storage batteries. OPNAVINST 5100.23B emphatically states that you must wear eye protection devices at all times and that emergency eyewash facilities must be immediately adjacent to, or within 10 feet of, any eye-hazard area. Smoking and spark-producing tools or devices are also prohibited in enclosed spaces that contain lead-acid storage batteries. When charging, these batteries produce sufficient quantities of hydrogen to produce large explosions. **Lead-acid storage batteries should only be charged in well-ventilated spaces.**

Q-24. Emergency eyewash facilities must be located within what minimum number of feet of an eye-hazard area?

DRY BATTERIES

You must periodically check dry cell batteries that are used for test instruments and portable or field equipments for loss of power. For actual voltages of dry batteries, you should measure with a battery tester for a minimum acceptable voltage before installation. The TS-183/U series of battery testers incorporate a multiple-range voltmeter, battery-loading resistors, multiplier resistors, and a jack-switching arrangement that connects the load resistors across the voltmeter for a total of 32 different voltmeter-load resistor combinations. This type of tester permits you to complete a rapid and accurate measurement of battery potentials under load conditions, ranging in voltages from 1.5 to 180 volts. A data chart supplied with the battery tester provides information regarding the jack to be used and minimum acceptable voltages of various batteries used in Navy equipments.

Q-25. What is the advantage of using a battery test set versus a voltmeter to test batteries?

Table 2-2 shows general standards of tolerance for dry batteries. Whenever practical, dry cell batteries that are not in use should be stored in a refrigerated area to extend their shelf life.

Table 2-2.—Typical voltage Tolerances for Dry Cell Batteries

RATED VOLTAGE	MAX. VOLTAGE TOLERANCE
1 to 2	0.1
3 to 10	0.3
11 to 15	0.5
16 to 25	1.0
26 to 50	2.0
50 to 70	3.0
70 to 99	5.0

CARBON-ZINC AND ALKALINE BATTERIES

Carbon-zinc and alkaline cells are used primarily in portable test equipment, vom's, flashlights, some portable radios, and beacon equipment. The carbon-zinc cell provides 1.5 volts and holds its charge for approximately 1 year in normal service. The alkaline cell provides 1.2 volts and has about twice the stored energy of the carbon-zinc cell of the same size. It also has a longer life at a higher discharge rate than the carbon-zinc cell. You should discard both types of batteries at the first indication of weakness.

MERCURY CELLS

The storage life of a mercury cell varies but is generally classified as *long*. The working life of the cell is extremely long relative to other types of batteries; and it maintains its full rated voltage (1.34 volts) until just before it is ready to expire, at which point its voltage will drop off sharply. Recharging of mercury cells is possible, but is not recommended because the recharging cycle can vary from one cell to another; and, after being recharged, their operating lifetime is uncertain.

NICKEL-CADMIUM BATTERIES (NICAD)

Nickel-cadmium batteries have very high efficiency. They can be recharged hundreds of times; given the proper conditions, they may even be recharged thousands of times. They can be stored for a number of years with no significant loss of performance. After just a few charge and discharge cycles, NICAD cells can be recharged to the point that they are just as good as new batteries. Since they are sealed, they are maintenance free and can be installed in any position. There are two types of nickel-cadmium batteries — vented and nonvented. This description deals with the nonvented exclusively because a vented NICAD would have extremely limited application in a shipboard environment.

The voltage at the terminals of a NICAD will normally be between 1.25 and 1.30 volts in an open-circuit condition. This value will vary, of course, depending on the state of charge. If the charge has dropped to a low of 1.1 volts, the NICAD should be regarded as being completely discharged and should not be permitted to be discharged further. The majority of small NICADs are rated in milliampere hours; the large ones are rated in ampere hours. The small NICAD is the one the technician will almost always be concerned with.

Q-26. At what voltage is a NICAD battery considered to be fully discharged?

As a general rule, if the charging current is held to 10% of the milliampere-hour rating for the NICAD and the time of charge is held at 150% of the time required to establish its full milliampere-hour rating, you will encounter no difficulty in maintaining NICADs at their maximum charge. For example, you should charge a battery rated at 300 milliampere hours for 15 hours at 30 milliamperes. You can leave the battery on extended charge for years, provided the charge rate is lowered to less than 10% of the NICAD's milliampere rating.

You should never place a NICAD in your pocket, because metal objects (such as keys) can short the cell and cause extreme heat. Never dispose of a NICAD by fire, because it can explode. Never solder a connection directly to the cell, because the heat of an iron can damage it. Never overcharge a NICAD cell, because an accumulation of gases within its case can destroy it.

NICADs are also subject to a phenomenon commonly referred to as cell *memory*. If a NICAD is consistently discharged to a minor extent (for example, 30 minutes per day) and then recharged after each use, the useful capacity of the cell will eventually be reduced to that level. To keep this from happening, you should fully discharge (1.1 volts) NICADs on a regular basis. In fact, some maintenance requirement cards and calibration laboratory procedures require this periodic full discharge of equipment containing NICADs.

RF ATTENUATORS AND RESISTIVE LOAD TESTS

All rf attenuators, decade or step attenuators, decade resistors, and 50/75-ohm loads are clearly marked to show their attenuation factor or resistance. In the case of precision rf attenuators, they are usually marked to show their useful frequency ranges. They are all basically resistive devices and are designed for a multitude of applications. None of these devices are user-repairable; however, you should be aware of the different methods of determining whether or not they are functioning properly.

FIXED RF ATTENUATORS

Fixed rf attenuators (shown in fig. 2-28), such as the ones commonly found in power-measuring sets, are designed to provide a fixed-signal attenuation over a specific frequency range. Frequency ranges can be in excess of 30 gigahertz, and attenuation factors are typically in 1-, 3-, 6-, and 10-dB steps. Fixed attenuators can be connected in series to provide you with the desired attenuation. Most fixed rf attenuators are designed to handle only small amounts of rf power and are extremely susceptible to damage because of overloading. To test a fixed rf attenuator, you can either substitute it with a known good attenuator or perform basic measurements on the attenuator itself. With the rf substitution method, you connect an rf signal generator to a power meter and establish a suitable reference point on the meter by adjusting the power output of the signal generator. Once you establish the reference point, insert the rf attenuator between the signal generator and the power meter. You then determine the attenuation by noting the difference between the power meter reading and the initial reference point.

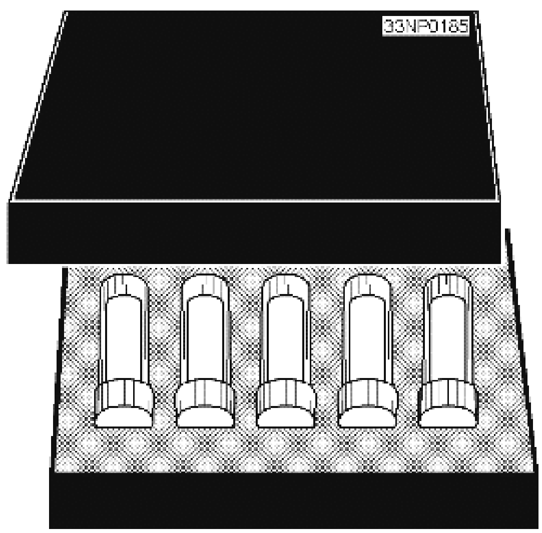

Figure 2-28.—Fixed attenuator set.

Q-27. What is the most common method of testing a fixed rf attenuator?

DECADE RESISTORS

Decade resistors (also referred to as decade boxes) typically are precision devices. Depending on the make and model of the decade resistor, it may be capable of providing you with a selection of resistors ranging in value from a small fraction of an ohm to hundreds of megohms. Decade resistors are commonly used in calibration laboratories and in engineering design applications. Like the fixed rf attenuator, most decade resistors are capable of handling only small amounts of current. They are very limited in respect to frequency capabilities and are commonly used in dc-circuit applications. You may encounter specific equipment that requires the use of a decade resistor in performing your maintenance tests or alignments. To test a decade resistor, you can connect a standard multimeter or digital multimeter directly across its resistance terminals and read its resistance on the meter. This test will only indicate gross errors in the decade resistor such as an open or a badly damaged resistor. If you are performing a precision measurement or an alignment using a decade resistor and have any doubt as to its accuracy, you should submit it to your servicing calibration laboratory. Figure 2-29 shows a typical decade resistor.

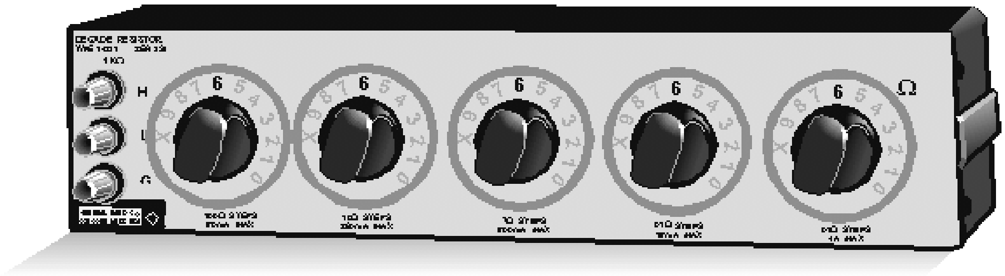

Figure 2-29.—Decade resistor.

DECADE (STEP) ATTENUATORS

Decade attenuators (also referred to as step attenuators) are common devices that may be designed as either a stand-alone piece of test equipment or as an integral part of an operational piece of electronic equipment. As the name implies, they are used to attenuate rf signals in incremental steps. Like the fixed rf attenuator, you can easily test them by using the rf substitution method, as previously described. Views A and B of figure 2-30 show two types of decade attenuators.

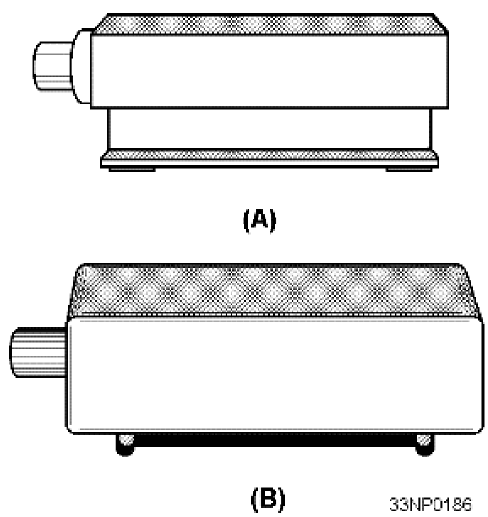

Figure 2-30.—Step attenuators.

50/75-OHM TERMINATIONS

Terminations of 50 and 75 ohms are designed as either feedthrough, impedance-matching devices, or as rf loading devices. They are precision resistors sealed in small plastic or metal enclosures and are designed to be mounted on various rf connectors. In the case of feedthrough terminations, they are designed with rf connectors at both ends, which allows the rf signal to pass through them. They are impedance-matching devices designed primarily to reduce the voltage standing-wave ratio (vswr) that is produced when two pieces of equipment with dissimilar impedances are connected together.

You can test a feedthrough termination by measuring the resistance between the center conductor and the shield of either rf connector with an ohmmeter. As mentioned above, some terminations are manufactured as loading devices that are designed to shunt an rf signal to ground. A perfectly matched termination can be compared to a transmitting antenna in that it absorbs all of the rf signal with only a small amount of power being reflected back to the transmitting device. When using a termination as a load, you should ensure that its wattage rating exceeds the power output of the equipment to which it is connected. You can also measure this type of termination by using a standard ohmmeter to read the resistance between the center conductor and the shield of the rf connector.

Q-28. What is the most common method of testing resistive terminations?

FIBER-OPTIC TESTING

Fiber optics are a relatively new type of transmission media. Figure 2-31 depicts a typical fiber-optic cable design. The core of the fiber-optic cable is the optical transmission path, which carries data from the optical transmitter to the optical receiver. The core is usually made of plastic, glass, or plastic-clad silica (PCS). Glass-core fibers are usually smaller in diameter than plastic or PCS cores. The major disadvantages of glass cores are that they have high attenuation (25 dB/km), require precision tools and connectors, and are extremely susceptible to mechanical damage. Plastic cores are typically more rugged than other types of cores, but their attenuation is high (35 dB/km). PCS cores are fairly rugged and have a relatively low attenuation (10 dB/km). A fiber-optic cable may consist of one fiber, multiples of single-optical fibers, or bundles of optical fibers. Fiber-optic cables are well suited for the transmission of high-speed data over relatively short distances. They are virtually immune to crosstalk or interference through inductance. (Interference is a characteristic of metallic cables.)

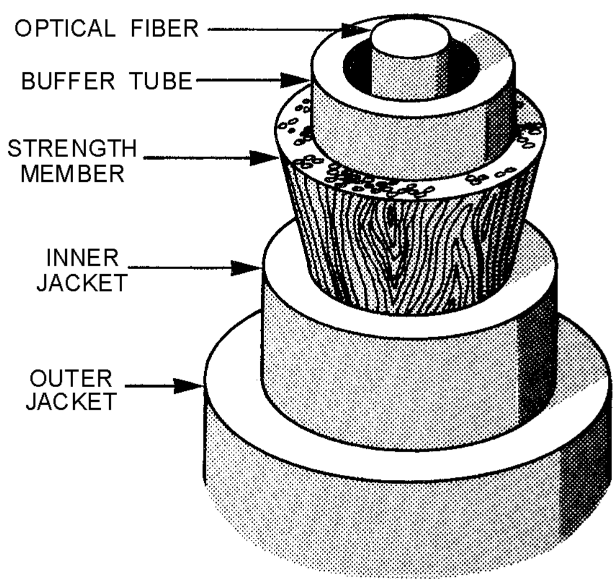

Figure 2-31.—Typical fiber-optic cable.

Testing techniques and the principles of measurement for fiber-optic and conventional cable are similar. For example, if both ends of the cable are exposed and can be used for testing, relatively unsophisticated equipment can be used to measure cable parameters, such as continuity and attenuation. This includes equipment such as optical multimeters and optical power meters (OPM). If only one cable end is available, then more sophisticated equipment such as an optical time-domain reflectometer (OTDR), is used. The following section lists and defines some common optical test equipment.

Q-29. What is the main disadvantage of using fiber-optic cables?

OPTICAL TIME-DOMAIN REFLECTOMETER (OTDR)

The portable optical time-domain reflectometer (OTDR) is used to check loss at each splice, at each connector, and of the entire system. Loss measurements are figured by using the same methods you would use for wire loss measurements. The OTDR injects a short, intense laser pulse into the fiber and monitors reflections caused by breaks, inclusions, microcracks, and discontinuities. Discontinuities appear as a spike on the OTDR display. The loss at the discontinuity point is directly related to the distance between the major pulse triggered by the laser and the spike. The manufacturer's manual provides you with conversion factors to figure actual losses and locations of the discontinuities.

OSCILLOSCOPE

An oscilloscope is used with an OTDR to provide visual evidence of fiber faults, connector and splice locations, and attenuation locations.

OPTICAL MULTIMETER

The optical multimeter measures light sources and light in cable and at the detector, fiber cable transmission loss, and connector splice loss. For cable transmission measurements, transmission through a short length of cable is compared with transmission through a known longer length.

OPTICAL OHMMETER

The optical ohmmeter measures the input versus the output of light in an optical fiber. It displays attenuation losses based on a comparison of known and unknown cable signals. It can be used in manufacturing, connecting, and installing cable. It is as simple to use as a digital voltmeter.

OPTICAL POWER METER

The optical power meter measures current by converting light power from plug-in units, such as light emitting diodes, into electrical current. In some models, the readout is in power units, watts. In other models, the readout is in absolute power levels and attenuation. Some units operate with a variety of power sensors for conventional coaxial and waveguide systems and fiber-optic systems.

RADIOMETER/PHOTOMETER

The radiometer/photometer measures light power in watts from dc to unlimited ac response. It uses plug-in sensor heads and, for low-light displays, it uses spectrometers and fiber-optic measurements.

AUTOMATIC TEST EQUIPMENT

Automatic Test Equipment (ATE) is test equipment designed to evaluate the operational performance of a piece of equipment or printed circuit board (pcb). ATE assists you in troubleshooting a fault to the defective component. Basically, ATEs are state-of-the-art, computer devices in which software programs are specifically tailored to meet the requirements of the device being tested.

The AN/USM-465 Portable Service Processor (psp), shown in figure 2-32, is the Navy's standard ATE for testing digital pcb's.

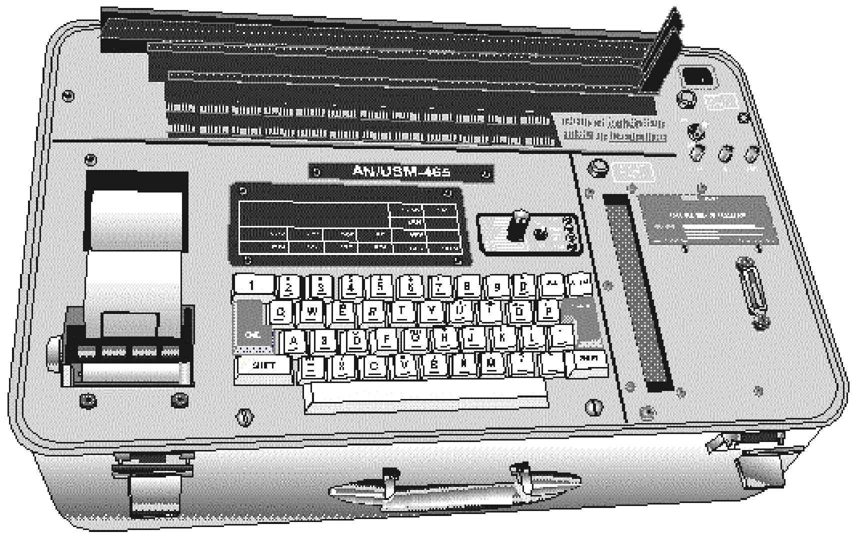

Figure 2-32.—AN/USM-465 Portable Service Processor.

The AN/USM-465 is part of the Support and Test Equipment Engineering Program (STEEP). It provides on-site screen testing and fault isolation of digital pcb's and modules. The psp is presently available on most ships and shore intermediate maintenance activities (SIMA) with Mini/Micro maintenance stations (2M). Psp's come with maintenance-assist modules (spare parts kit) and diagnostic kits.

The psp is easy to use. You have a choice of three pcb connectors (located on the top panel of the test set) into which you insert the pcb being tested. The software program, which is provided on magnetic tape cartridges, is then loaded into the test set. The test set automatically tests the pcb by applying input signals to the appropriate pins while monitoring the output signal for a correct indication. An LED display will give you a pass or fail indication. If a pcb fails the operational test, the psp tells you (via LED display) what troubleshooting steps must be taken. The psp uses a *guided probe* fault isolation technique that tells you what test points to check on the faulty pcb. The software program guides you from the faulty output backwards toward the input until the fault is located. The probe is a standard 10 megohm, 10 to 1 oscilloscope probe. The guided probe circuitry and software is also unique because it is capable of locating faults within feedback loops and can sense when you have placed the probe at an incorrect test point.

An interesting advantage is that if the psp itself fails, the faulty board inside the psp can be identified by the test set's own capability. After you replace the faulty pcb with a good one from the spare parts kit, you can use the psp to identify the faulty component on its own pcb.

HUNTRON TRACKER 2000

The Huntron Tracker 2000, shown in figure 2-33, is a versatile troubleshooting tool used to statically test resistors, capacitors, inductors, diodes, transistors, multiple-component circuits, and integrated circuits. Its built-in features eliminate the use of multiple pieces of test equipment. These features and its lightweight portability make the 2000 a widely used tool for troubleshooting.

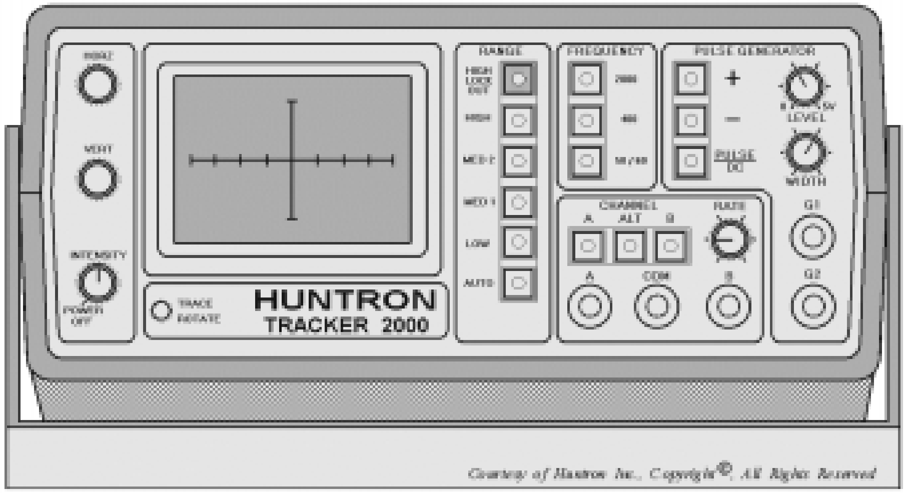

Figure 2-33.—Huntron Tracker 2000.

We recommend you review setup and operating procedures discussed in NEETS Module 16, *Introduction to Test Equipment*, NAVEDTRA B72-16-00-95, before continuing with this chapter. Since the 2000 was covered in depth in module 16, we will cover only the most common troubleshooting procedures and provide a few troubleshooting tips.

Q-30. What two features make the Huntron Tracker 2000 a widely used troubleshooting tool?

The Huntron Tracker 2000 has the following features:

- Multiple-test signal frequencies (2000 Hz, 400 Hz, and 50/60 Hz).
- Four impedance ranges (low, medium 1, medium 2, high).
- Automatic range scanning.
- Range control: High Lockout.
- Rate-of-channel alteration and/or range scanning is/are adjustable.
- Dual-polarity pulse generator for dynamic testing of three terminal devices.
- LED indicators for all functions.
- Dual-channel capability for easy comparison.
- Large CRT display with easy-to-operate controls.

CAUTION

The device to be tested must have all power turned off, and have all high voltage capacitors discharged before connecting the Tracker 2000 to the device.

Testing Components by Comparison

Testing components by comparison is the most preferred method for troubleshooting. The ALT (alternate) mode setup is the most commonly used mode for this method. This mode allows the technician to compare a known good component to a suspect component. This is accomplished by connecting channel A to a known good device, channel B to the device under test, and a common test lead to COM as illustrated in figure 2-34. Select the ALT button, and the 2000 will alternately display the signature of the known good device and the device under test. By examining the signature differences, you can detect a defective component. Figure 2-35 is a typical example of the CRT display on the 2000 while testing the base to emitter on a good transistor. Figure 2-36 illustrates a defective transistor under the same test setup. Note that in the low range, the transistor appears to be good. Sometimes component defects are more obvious in one range than another, so is a suspect device appears normal for one range, try the other ranges.

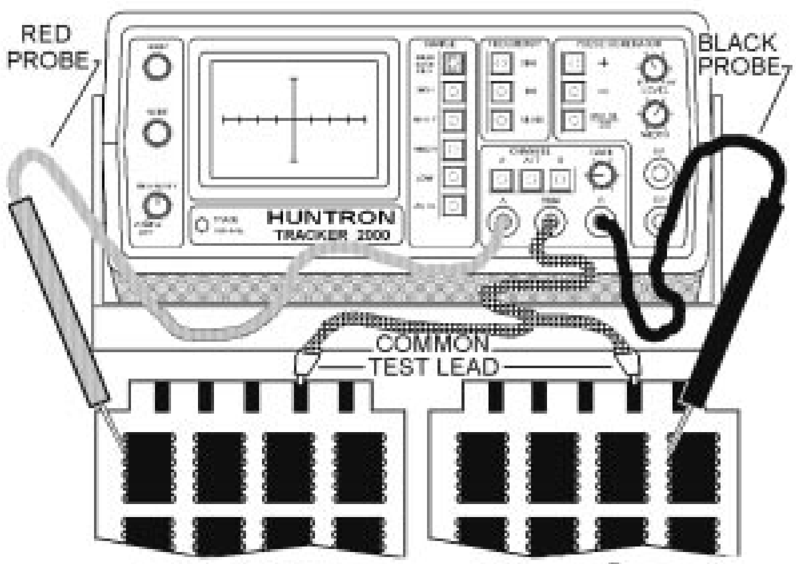

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Figure 2-34.—Alternate mode setup.

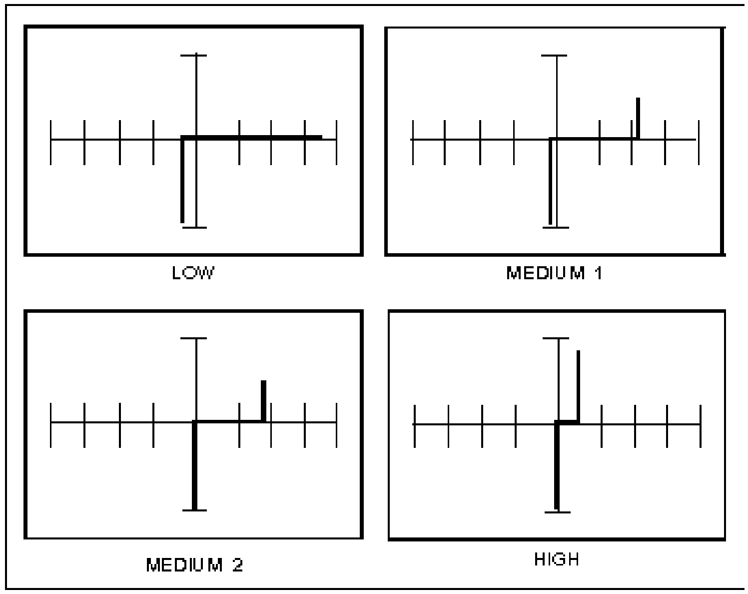


Figure 2-35.—Signatures between base-emitter of a good transistor.

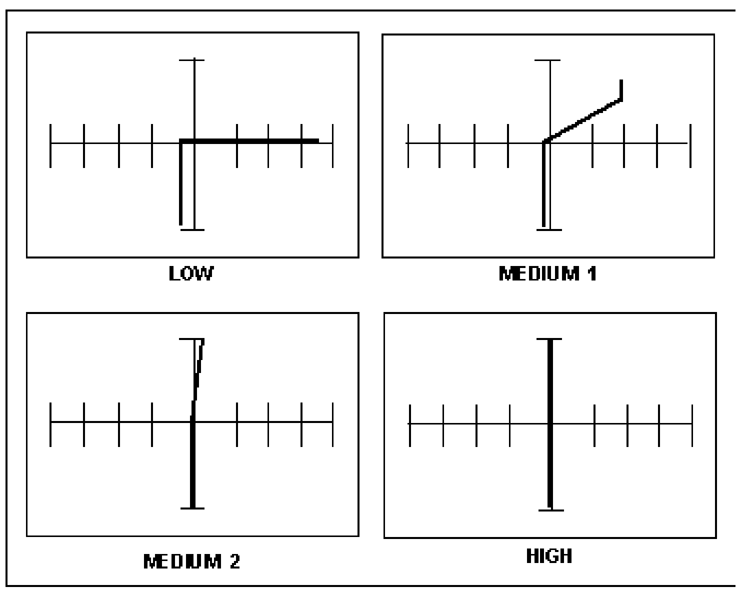


Figure 2-36.—Signatures between base-emitter of a defective transistor.

Q-31. What is the most preferred method of troubleshooting?

Q-32. Why is it recommended to use more than one range while troubleshooting a device?

Troubleshooting Tips

When you are testing individual components in a circuit, a parallel resistor or diode of similar value may cause a defective component to appear good. Therefore, you should, in most cases, electrically isolate the suspected component from the circuit while testing individual components. The best way to do this is to desolder all but one lead on the suspected component.

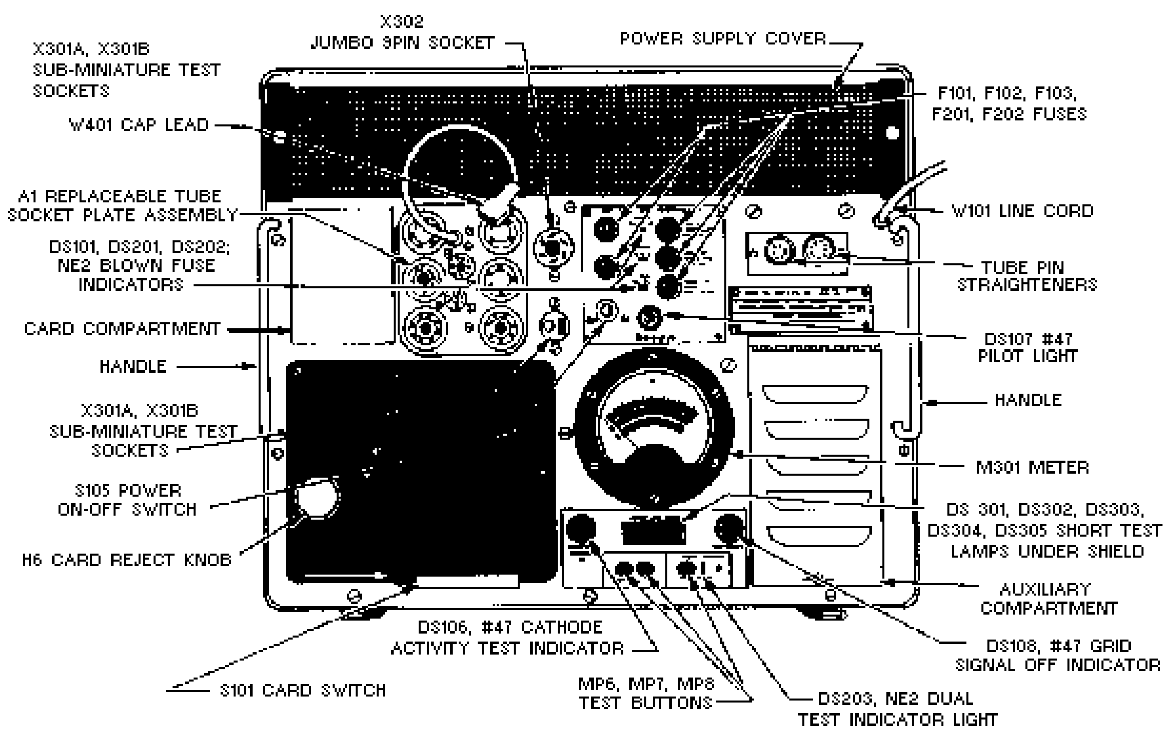
Q-33. When you are testing individual components in a circuit, what may cause a defective component to appear good?

You should be aware that devices made by different manufacturers may appear to have slightly different signatures. This is normal, especially with digital integrated circuits, and does not necessarily indicate a failed device. When this occurs, the best way to verify this is to compare the outputs of the device under test with the equipment specifications to ensure the signals are adequate for proper equipment operation.

SUMMARY

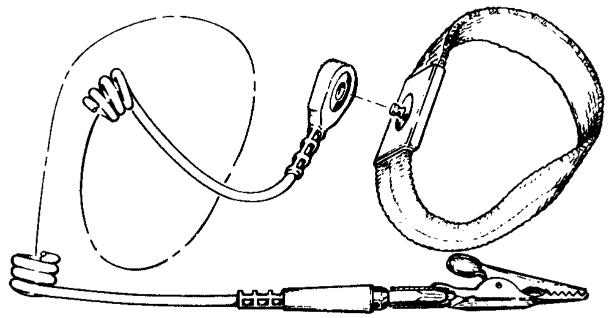
The information that follows summarizes the important points of this chapter.

ELECTRON TUBES are usually tested for **SHORTS, TRANSCONDUCTANCE**, and the presence of GAS. Several different types of tubes (i.e., twt's, magnetrons, and klystrons) are normally tested in-circuit.



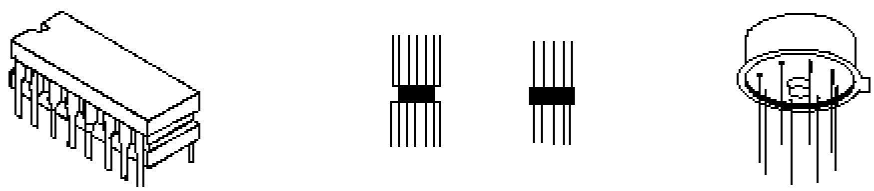
Most **TRANSISTORS** can be tested by measuring the forward-to-back resistance of their junctions using a standard ohmmeter. The resistance scale of the ohmmeter must be carefully selected to ensure that the current rating of the transistor is not exceeded.

ESD-SENSITIVE DEVICES are components that require special handling. Some of the more sensitive devices can be damaged by static charges as small as 35 volts.



Most **DIODES** and **MOSFETs** can be tested by measuring the forward-to-back resistance of their junctions using a standard ohmmeter. MOSFETS, however, are classed as ESD-sensitive devices; and care should be exercised when handling or testing them.

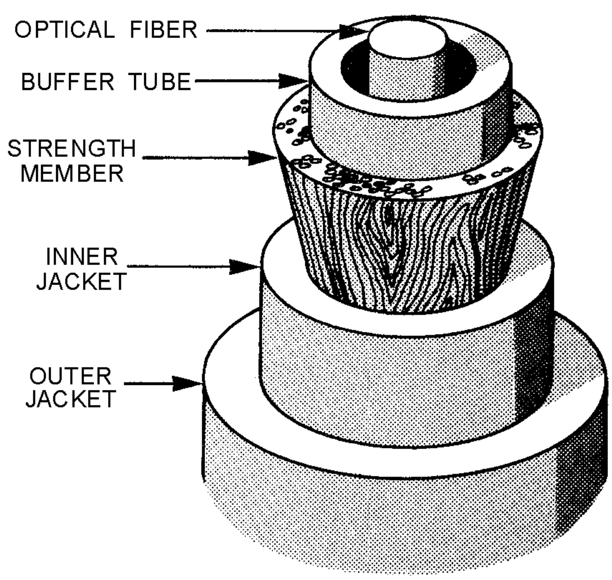
INTEGRATED CIRCUITS (ICs) have revolutionized the electronics industry. They are rugged, compact, and inexpensive. There is a wide assortment of equipment on the market designed for testing ICs.



BATTERIES are common to a large number of both electronic test equipment and operational equipment. You should be familiar with the different types of batteries, their test requirements, and the safety precautions to be followed.

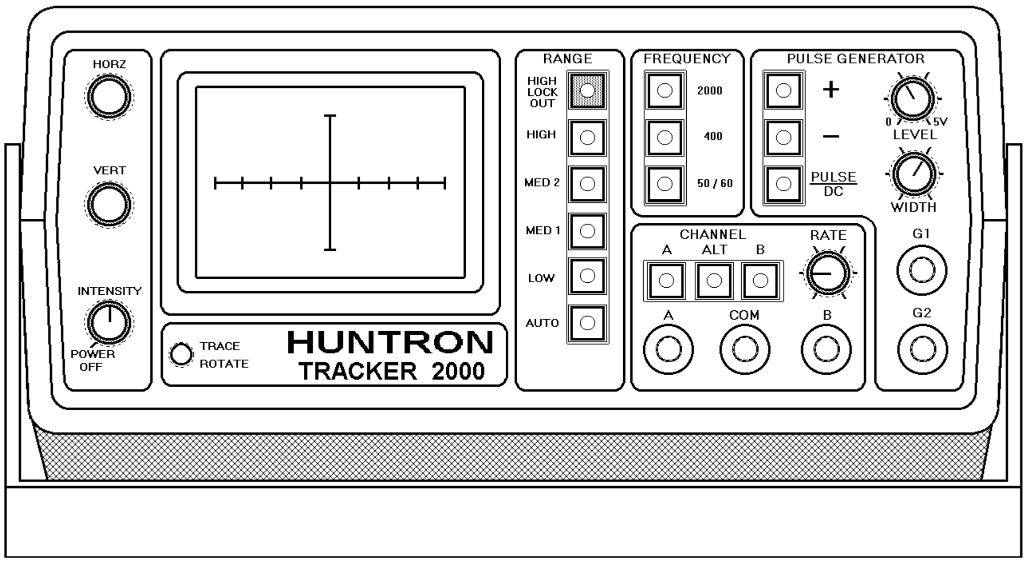
RF ATTENUATORS and **RESISTIVE LOADS** are common devices that are widely used for attenuating rf signals and impedance matching. Resistive loads can be tested with a standard ohmmeter, and rf attenuators are normally tested through the rf substitution method.

FIBER-OPTIC CABLES are used primarily for the transmission of high-speed data over short distances. Their construction and theory of operation require that they be tested with a light source, usually a laser beam. There is a wide assortment of test equipment designed specifically for testing fiber-optic cables.



AUTOMATIC TEST EQUIPMENT (ATE) is test equipment designed to evaluate the operational performance of a piece of equipment or printed circuit board (pcb).

The **HUNTRON TRACKER 2000** is a versatile troubleshooting tool commonly used for statically testing resistors, capacitors, inductors, diodes, transistors, multiple-component circuits, and integrated circuits.



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ANSWERS TO QUESTIONS Q1. THROUGH Q33.

A-1. Lack of adequate storage space.

A-2. Open filaments.

A-3. Testing the tube in its circuit.

A-4. In their circuit.

A-5. Restore it to serviceable condition by operating it temporarily at reduced beam voltage.

A-6. Correct gain figure.

A-7. Rugged design.

A-8. Sensitive to heat and minor overloads.

A-9. Any range setting that produces a current flow through the transistor that exceeds 1 milliamp (usually R x 1 range).

A-10. 3,500 to 4,000 volts.

A-11. 35 volts.

A-12. For your own safety.

A-13. Voltages and resistances.

A-14. Greater than 10 to 1.

A-15. Gate and anode.

A-16. Current is allowed to flow in either direction.

A-17. Solder suckers create an electrostatic charge capable of damaging a MOSFET.

A-18. Low power consumption, compact size, and lower cost.

A-19. ICs cannot be repaired. All you need to test is output versus input.

A-20. A "1" or "0."

A-21. A "1" state.

A-22. A difference in logic states between the reference IC and the IC under test.

A-23. They provide you with a visual indication of the logic state at any point you choose in the circuit.

A-24. 10 feet.

A-25. A battery test set will test batteries under load conditions.

A-26. At 1.1 volts.

A-27. Rf substitution method.

A-28. Reading their resistances with a standard ohmmeter.

A-29. High attenuation.

A-30. It eliminates the need for multiple pieces of test equipment and it is lightweight and portable.

A-31. Testing components by comparison.

A-32. Some defective devices may appear to be good in certain ranges.

A-33. A parallel resistor or diode of similar value.